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CONVENTION NEWS

The twenty-ninth annual meeting of the Central Association of Science and Mathematics Teachers will go down in the history of the Association as one of the finest and most inspiring gatherings. Certainly it marks the beginning of a new era in the growth of the Association. If the Cleveland meeting is an indication of the nature of future meetings, one can safely state that the Central Association has passed the meeting stage and is now in the convention stage.

Mr. Frank R. Bemisderfer, last year's President, and his associates who did everything humanly possible to make the meeting a success are to be highly commended and are deserving of a vote of thanks from the members of the Association. Certainly the visitors to Cleveland are indebted to them for the hospitable manner in which they were welcomed to Cleveland. The Cleveland teachers have set an example that will be well worth while for future groups to follow.

Over two hundred new members joined the association and a new section composed of elementary science teachers has been added. This group numbers well over one hundred and from all indications will add much to the credit of the Association by serving the elementary science teachers of the country.

The section meetings were well attended and papers of vital interest to the classroom teacher were presented. The general meetings were more than well attended. Owing to the fact that some of the country's outstanding personalities were on the program the public clamored for admission to these sessions and so insistent were they in their demands that it was deemed advisable to admit them to the meetings at a nominal charge.

The annual dinner, held in the ballroom of the Cleveland Hotel was a real feature of the convention. Dr. Luckiesh, Director of the Lighting Research Laboratory of the General Electric Company at Nela Park, Cleveland, gave a spectacular address on the subject of Let There Be Light. The attendance at this dinner broke all records, there being present 316 people. After hearing this stimulating address those present felt that they were repaid tenfold for their attendance.

One wonders how our conventions could function without the guidance and stimulation of some of the pillars of the Association. The Cleveland Convention will be long remembered because of their presence.

What would we do without Mr. Charles Marple of Cleveland who has retired from active teaching, and who spent most of his time during the year in traveling through Ohio getting members for the Association?

The members present at the Saturday morning meeting were both thrilled and delighted to have presented to them that elegant and scholarly gentleman Mr. James H. Smith of Chicago. Mr. Smith was president of the Association in 1909 when it met in Cleveland. He has also retired from active teaching, having taught at Austin High School for a number of years. However, his retirement has not interfered with his activities and his interest in the Association.

Another of the old guard who seemed to enjoy himself at the meeting was Mr. Charles M. Turton, one of the founders of the journal. Mr. Turton holds the record of not having missed a meeting. He is also on the retired list having taught at Bowen High School, Chicago, Illinois.

Professor H. E. Slaught of the University of Chicago, and Professor Louis C. Karpinski of the University of Michigan, both honorary members were seen attending the meetings and chatting with friends.

Members of the Association were glad to renew acquaintance with Professor Otis W. Caldwell of Teachers College, the second president of the Association.

We were also pleased to see one of the organizers of the Association, Dean Warren Hawthorne of Crane Junior College, Chicago, Illinois.

Other past presidents very much in evidence and working in behalf of the Association at the Cleveland meeting were Franklin T. Jones of Cleveland, Jerome Isenbarger and Glen W.

Warner of Crane Junior College, Chicago, Miss Ada L. Weckel of Oak Park High School, Oak Park, Illinois, Prin. Walter G. Gingery of Washington High School, Indianapolis, Indiana, W. F. Roecker, Boys' Technical High School, Milwaukee, Wisconsin, and Professor Walter W. Hart, University of Wisconsin.

CHARLES A. STONE

THE NEW OFFICERS OF THE ASSOCIATION

President: Dr. Charles A. Stone, The University of Chicago.

Vice-President: Mr. E. O. Bower, East Technical High School Cleveland.

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THE THIRTIETH ANNUAL MEETING

The next annual meeting will be held in Chicago the Friday and Saturday following Thanksgiving Day 1933. Plans for this meeting are now well under way. A Membership Application Blank will be found on another page of this issue. The officers urge that each of these blanks be used to enroll a new member. Join now to secure all the issues of Volume XXXIII of the official journal, SCHOOL SCIENCE AND MATHEMATICS.

BLEED SCHOOLS RATHER THAN CHANGE POLITICS

Undoubtedly in the hysteria of inflation the schools, like the colleges and universities, did some things that they can now do without. But the things that communities propose to do to them in the hysteria of economy far surpass the wildest aberrations of bull-market days. We hear a great deal about frills. What are frills? Teachers' salaries appear to be frills in some cities. The health of school children is a frill in others. Since night schools are a frill in one community, we close them and throw 75,000 people into the streets. The plain fact is that the schools are under attack because it is easier to get money from them than it is to correct the fundamental iniquities and antiquities of local government. Only a people that had no conception of the place of education in its national life could contemplate the ruin of the next generation as the best remedy for governmental insolvency.—ROBERT M. HUTCHINS, *President, University of Chicago.*

THE RÔLE OF PHYSICS AND CHEMISTRY IN BIOLOGY AND MEDICINE*

By George Crile, M.D.
Cleveland Clinic, Cleveland, Ohio

Mr. Chairman, Members of the Central Association of Science and Mathematics Teachers, Ladies and Gentlemen:

When Mr. Marple extended to me an invitation to address your meeting, I gladly accepted the assignment as a tribute which you have graciously paid the profession of medicine which is engaged in the baffling task of discovering new facts which will be helpful to the sick man. Moreover this invitation has given me the opportunity of paying tribute to the men who are working in pure science, without which medicine and medical science could have made no progress. I speak with the greatest reservation before this audience for I can lay no claim to any qualification in the difficult fields that you have created and are creating, and in which you are teaching.

Medicine and biology are rapidly becoming applied sciences of physics and chemistry. To physics we owe the possibility of the diagnosis and treatment of many diseases by the x-ray and radium; the application of the principles of optics in the treatment of vision; the restoration of the power of speech to the patients deprived of the larynx; knowledge of the mechanics of the heart and circulation of the blood; the instruments employed in the diagnosis and treatment of diseases of the hollow viscera; the application of the principles of mechanics by orthopedic surgeons; the application of the principle of sound conduction in the treatment of defective hearing; the development of the microscope without which the development of bacteriology and histology would have been impossible. To chemistry we owe our knowledge of the composition of the blood and lymph; our knowledge of metabolic processes; the preparation of drugs, vaccines and serum; the solace of anesthetics and narcotics. Biochemistry is concerned in every problem of nutrition; it has discovered the potency of iodin and solved the problem of goiter; it has discovered insulin and given a definite control of diabetes; it has identified the hormones secreted by various glands and rescued the cretin and the giant. This is but a brief statement regarding an enormous debt, for practically no field

* An address delivered at the Annual Meeting of the Central Association of Science and Mathematics Teachers, Cleveland, November 25, 1932.

of medicine or biology can be cited in which these sciences are not concerned.

I shall now endeavor to indicate problems in medical science to which mathematics, physics and chemistry offer the only means of approach, and I hope to enlist your aid in identifying the nature of protoplasm, in other words, the nature of the living processes in health and in disease.

PHYSICAL CHARACTERISTICS OF LIVING ORGANISMS AND CELLS

Physics identifies an animal—its height and length, its mass, its weight, its specific gravity, its color, its temperature, its movements, the texture and appendages of its skin, the size, the color, the weight of every organ and tissue, and of every cell that makes up the organs and tissues as revealed by the microscope. That is to say, the gross and microscopic structure of animals offers merely a physical description, just as the word *battleship* connotes the physical description of a special type of vessel by the architect and the engineer.

The concentration of electrolytes in the fluids is measured by the physical constant, electric conductivity. The Nernst formula ($P.D. = 0.058 \log C_1/C_2$) expresses the potential difference between electrolytic concentrations on the opposite sides of semi-permeable membranes in living systems precisely as it expresses the potential differences in non-living systems. The Einstein mathematical formulae for the surface tension phenomena in living systems—a fundamental factor in living protoplasm—are identical with those for non-living systems.

The three physical constants, namely, the electric conductivity, electric capacity, and electric potential of cells, of organs, and of organisms are a measure of their power of growth, of function, and of resistance to infection during life and activity. At death the electric potential is reduced to zero and the anatomical and the histological components of the animal are resolved into the simple elements of the earth and the air.

The recognition of a cancer by the microscope depends on the physical arrangement of the cells which themselves, in turn, have certain physical characteristics; and cancer is now known to exhibit a sign of charge opposite to that of its surrounding tissues and a higher electric potential.

Not only do living cells exhibit physical characteristics in form and function but the action of the secretion of certain

glands, notably the thyroid gland and the adrenal glands, has certain physical characteristics. The thyroid secretion governs the electric conductivity, electric capacity, and electric potential of the tissues; that is, the thyroid gland governs the capacity of the organism for work. When the thyroid gland is removed, the value of these electric constants decreases, the electric potential finally reaching zero at death. Therefore, the function of the thyroid is the maintenance of the electric charge, or electric potential, of the cells of the organism at a certain level. If the potential is raised above a certain level, the resultant excessive function and activity of the cells constitutes a certain disease. That is to say, when the thyroid secretes too much there results the disease known as hyperthyroidism or exophthalmic goiter, a condition in which all the organs of the body become overactive, even to the destruction of the individual.

THE ESSENTIAL ROLE OF ELECTRIC POTENTIAL IN LIVING ORGANS

We can now offer direct physical evidence of the essential role of electric potential in living organisms.

In a research in collaboration with Dr. Maria Telkes and Miss Amy F. Rowland, it was demonstrated in experiments on fruit, on plants, on the ameba and on animals, that when the electric potential was reduced to zero, all other factors remaining the same, the plant, the fruit, and ameba, the animal, disintegrated.

Moreover it was found that the progressive weakness which results from unchecked hemorrhage, uncontrolled infections, overwhelming emotions, prolonged loss of sleep, overwhelming shock, is accompanied by a progressive decrease in electric conductivity, in electric capacity and in the electric potential which was reduced to zero at death.

It was found also that such anesthetics as chloroform, ether and nitrous oxide, and such narcotics as morphine, luminal, amytol, etc., depressed the electric potential of tissues and organs. In general, we found that the physical well-being of the organism can be expressed in terms of millivolts of electric potential.

Dr. Telkes was able to insert an electrode into an ameba and to measure the electric strain across the membrane surrounding it. The usual potential difference between the ameba and the

surrounding medium was around fifteen millivolts. At this potential level the ameba was active. When the potential was lowered by introducing a current of the opposite sign of charge, no other change being made, the activity of the ameba diminished with the fall in potential and when the potential reached zero the ameba slowly disintegrated. When the ameba began to disintegrate, if the electrical potential was raised, the ameba not only repaired itself but showed activity. Thus, at will, the effect on the ameba of changing the single factor of electric potential could be observed under the microscope.

These clear cut experiments on the ameba, whereby the activity of the ameba was found to be governed by its electric charge, are in accord with one of the most fundamental facts in general physiology; namely, that electric stimulation of the nerve supplying an organ, that is, electric stimulation of the protoplasm of the organ, will increase the work done by the organ, that is, by the protoplasm. In other words, electric stimulation is the equivalent of biologic stimulation. This is one of many proofs that might be given that electric processes observed in living systems are identical with electric processes observed in non-living systems.

COMPARISON BETWEEN NITRO-EXPLOSIVES AND PROTOPLASM

There is a striking parallel between the composition and the properties of the nitro-explosives and protoplasm. In both the nitro-explosives and protoplasm the major part of the energy is carried in the carbon fraction, but in the great carbon group there is incorporated the bound nitrogen group.

In their fundamental aspects, the nitro-explosives behave chemically and physically like protoplasm. Take, for example, a frog's muscle. The muscle consists of carbon compounds into which are incorporated bound nitrogen groups, just as in nitrocellulose, nitroglycerine, and T.N.T., bound nitrogen groups are in chemical combination with carbon compounds. When the muscle contracts, it gives off carbon dioxid, ammonia, and water, and generates radiant and mechanical energy. Dr. Otto Glasser, in the Physics Laboratory of the Cleveland Clinic Foundation, has demonstrated the emission of radiation on the order of ultraviolet light during the contraction of a frog's heart. When nitroglycerine is exploded, carbon dioxid, free nitrogen and oxygen, water, and radiant and mechanical energy are given off.

THE "ALL-OR-NONE" LAW

Another common physical property is possessed by nitro-explosives and by muscle, namely, both nitro-explosives and muscle will either not respond at all or they respond to explode completely. Each obeys the all-or-none law. A physical blow may "explode" each; an electric charge may "explode" each. Berthelot has shown that in a mass of nitro-explosives a definite wave of explosion passes over the mass. In the process of contraction, a wave of contraction passes over a muscle. A blow upon the head will exhibit to the subject the sensation of light and of sound. Presumably, the blow detonates the sensitive fixed nitrogen compounds or proteins in the brain.

A striking example of a physical property in living organisms is the Gurwitsch radiation discovered by the Russian investigator of that name. Gurwitsch was not able to demonstrate this radiation directly, but he demonstrated it indirectly by the effect on cell division and growth when the tip of one onion root was placed against the side of another onion root. The presence of one growing tip had the effect of increasing the rate of cell division in the other onion tip.

Dr. Glasser was the first to demonstrate these radiations directly by purely physical methods, first, by securing photographs of the radiations, and later by recording them by means of a photo-electric cell and Geiger counter on a tape recorder and a loud speaker. Dr. Glasser has recorded such radiations from a frog's heart, from yeast, from cancer, and from the autosynthetic cells which will be described later.

EXTERNAL ORIGIN OF RADIATION OF LIVING ORGANISMS

The Gurwitsch rays are analogous to the rays producing the visible spectrum which are exhibited by many animals, notably the firefly; they are analogous to the infra-red radiation generated and emitted by virtually all animals and plants. That is to say, animals and plants generate and emit the components of the solar spectrum. It would indeed be strange were this not the case, as, so far as is known, the energy of life on the earth is derived directly or indirectly from the sun's radiance.

Since almost universally energy is derived from coal, and oil, and wood, and food, it is evident that the carbon atoms are the principal absorbers of the sun's radiance. The carbon atom in the plant cell receives and stores within itself the sun's radiance in the process of synthesizing carbohydrates.

Now, it is a physical fact that when an atom that receives energy of a certain wave-length, emits the energy received, the emitted energy will have the same wave-length or a longer wave-length, never a shorter wave-length, than that which was received. Therefore, when carbohydrates are burned or oxidized, there must be emitted the radiance put into the carbon atoms by the sun when the carbohydrate was formed. When wood, or coal, or oil is burned, radiance is emitted which ranges from ultraviolet radiation down through the visible spectrum through the infra-red. The same law must hold for living organisms, that is, the stored radiance of the sun must be set free from its captivity in the atoms. The radiations thus emitted supply the energy which organizes and drives living organisms.

Due to the unique attraction of carbon atoms for each other, the outstanding characteristic of carbon compounds are their long carbon chains and their stability, as illustrated by the stability of coal and oil. This suggests a most important fact, namely, there are no living organisms—plants or animals—microscopic or macroscopic—which consist of carbon compounds alone. From this fact, one would infer that carbon compounds alone are too stable for the organization and the operation of living organisms. In living organisms, the carbon compounds in every instance have bound with them a nitrogen group in the ever present proteins. This suggests that the bound nitrogen group confers the exquisite sensitivity which is characteristic of protoplasm.

INTERNAL ORIGIN OF RADIATION IN LIVING ORGANISM

As has been stated, the protoplasm of animals emits radiation of various wave-lengths, some as short, hence as powerful, as those emitted by the sun. It follows that an animal emits radiation that can change the electrons of atoms in the same manner that the sun's radiance changes the electrons of atoms. In other words, the sun "shines" in the protoplasm of animals and plants, and, therefore, animals and plants can confer on atoms chemical affinities such as are conferred by the sun. But to produce ultraviolet radiation of the wave-length of ultraviolet light, a temperature of from 3,000 to 6,000 degrees centigrade is required. This, applied to a human being, would seem preposterous. Who would think that there are "hot points" in man and animals on the order of the temperature of the surface of the sun? But if Gurwitsch, Dr. Glasser, and others are right in their experi-

mental evidence that ultraviolet radiation is generated in protoplasm, these facts must be harmonized.

Rutherford states that the chance of hitting a bird when shooting at random is as great as that of hitting an electron when an alpha particle passes through an atom. The chance of an x-ray collision with the proton or electron in an atom is as improbable as would be the chance of hitting a planet or the sun by throwing a snowball through the solar system. It is the inconceivably small size of the protons, the electrons, the atoms, and the molecules that makes it impossible for our minds to appreciate it—and at best the idea can only be crudely represented by parables and analogies. Only the conception that the hot points are infinitely small and the interspaces infinitely large in comparison can make acceptable the conception of a temperature as high as that of the sun itself in relatively cool protoplasm. The relatively free spaces between the atoms and molecules in protoplasm are vast, and it is because our minds are not accustomed to think in terms of the infinite that it is difficult to grasp this fact.

Although the sun has an outer temperature of from 5,000 to 6,000 degrees centigrade, a temperature which we conceive to be that of the infinitely small points which we may call the "suns" or "radiogens" in protoplasm, neither the solar system as a whole nor protoplasm as a whole has a high temperature. The solar system and protoplasm alike have only a moderate temperature because of the vast relative spaces in the solar system and in protoplasm wherein is absorbed the radiation emitted from the points of high temperature. In other words, it would appear that the sun's radiance has set up infinitesimal "suns" in protoplasm which generate and emit radiation identical with the sun's direct radiance on plant cells. That is to say, the sun shines with undiminished radiance in the protoplasm of animals. If one could look into protoplasm with an eye capable of infinite magnification, one might expect to see the radiogens spaced like the stars as suns in infinite miniature. We may say that protoplasm is a milky way consisting of "solar systems" infinitely diminutive, each created in its own image by the sun's radiance. The nucleus or "sun" of our theoretic radiogen would theoretically be a molecule of iron. Dr. Telkes has calculated, on the basis of the amount of iron present in muscle, that in a cubic centimeter of muscle there would be on the order of four billion radiogens or protoplasmic "suns." Those radiogens we may sup-

pose to be the exclusive mechanisms of energy transformation—exclusive centers of protoplasmic activity and growth.*

SIGNIFICANCE OF THE LABILITY OF NITROGEN COMPOUNDS

We have stated that carbon compounds are too stable to be available for the exquisitely delicate sensitive reactions of protoplasm and that universally the exquisitely sensitive bound nitrogen group is incorporated in protoplasm.

The free nitrogen of the air is chemically inert. This inertia of nitrogen is supposed to be due to the fact that the atoms of nitrogen have a great affinity for each other, and hence there is left no chemical affinity for oxygen, hydrogen, and other atoms. Under the powerful influence of lightning and of other high tension discharges, the pairs of atoms of nitrogen which are tightly bound together are torn asunder and each separate atom of nitrogen is thereby endowed with a powerful chemical affinity to combine with oxygen to form nitrogen peroxide. Nitrogen peroxide, in turn, is chemically unstable and in contact with water forms nitric acid. When nitric acid falls upon the soil and comes in contact with potassium compounds, nitrate of potassium is formed. And nitrate of potassium is one of the essential elements from which protoplasm is built up. Thus we see that the bound nitrogen group in protoplasm is in reality formed by lightning. According to Ernst and Sherman, of the Fixed Nitrogen Research Laboratory, in Washington, one hundred million tons of nitrogen are fixed annually by lightning and carried to the earth's soil by the precipitation of rain, snow and hail. But lightning is not the only form of energy whereby the powerful combination of two atoms of nitrogen can be broken up and each endowed with chemical affinities. Nitrogen atoms can be endowed with chemical affinities in utter silence, in the dark, and on a larger scale than by lightning. I refer to the work done by the nitrogen-fixing bacteria which are found in the soil everywhere.

Since protoplasm elsewhere generates and emits ultraviolet radiation, then we may suppose that the protoplasm of the nitrogen-fixing bacteria generates and emits ultraviolet radiation. Results obtained in the Fixed Nitrogen Research Laboratories in Washington, indicate that ultraviolet radiation so alters the structure of the nitrogen molecule as to render this

* The difficulty in making this calculation is that it is not known how much of the iron is "active." Other molecules such for instance as those of glutathione, etc., might act as "radiogens."

exceedingly inert substance chemically active. We may suppose, therefore, that the power of the ultraviolet radiation emitted by the nitrogen-fixing bacteria breaks the nitrogen atoms from their bonds, just as lightning does, leaving them free to combine with hydrogen and oxygen to form nitrates. Lightning and the sun are more spectacular sources of energy but we may suppose that they are not hotter at the point of contact with nitrogen than are the infinitely small "suns" in the protoplasm of the nitrogen-fixing bacteria. The original sources of the energy in the carbon compounds and of the energy in the nitrogen compounds in the living organism are from the sun and electricity, in other words, extra-terrestrial energy. These considerations suggest problems for further experimental attack.

THE ROLE OF THE BOUND NITROGEN GROUP IN PROTOPLASM

Let us now consider the role of the bound nitrogen group in protoplasm turning our attention to oxidation and nitro-carbon detonation.

Protoplasm, as has been stated, consists of a carbon compound linked with a bound nitrogen group analagous to nitro-glycerine, nitro-cellulose, or T.N.T. with respect to sensitivity, obedience to the all-or-none law, to being fixed by detonation, or by mechanical disturbance, to the genesis of radiant energy and to dissociation into carbon dioxid, into water, and into a nitrogen fraction. The sensitivity of protoplasm is approached in non-living systems only by the nitrogen compounds. Nitrogen chlorid presents an example of such exquisite sensitivity for nitrogen chlorid may be exploded by the disturbance due to the closing of a distant door, it may be exploded by the slightest touch of the fringe of an oiled feather, or by a beam of light.

MECHANISM OF SENSITIVITY IN LIVING ORGANISMS

From the above point of view, let us interpret the most perfect example of the detonation of nitro-sensitive compounds by radiant energy as shown in the reaction of the eye.

The eye as a photo-electric cell.—The retina of the eye is a projection of a specialized portion of the brain through a hole in the skull. Through the ophthalmoscope a living portion of the brain may therefore be seen in the process of receiving impressions and of creating images. These images, in turn, fabricate thoughts, memories, actions, emotions. Thus this part of the mechanism of imagery, of memory, of action and of thought,

can be seen while in action. Light waves which have photo-electric effects, that is, have the power of knocking off the outer electrons of the atoms of potassium, calcium, etc., are by this action able to set up two fundamental biologic processes—fundamental for all protoplasm, namely, the electrons thus freed set up biologic currents as similar electrons do in photo-electric cells, and the atoms which are thus modified by the loss of electrons have by that change become endowed with chemical affinities.

We may then suppose that this exquisitely sensitive nitrogen compound in the retina may be detonated by light waves just as a beam of light may detonate nitrogen chlorid. Thus the entire chain of events, from a passing image to an overwhelming emotion, could be initiated and executed by the detonating impact of the radiant energy of light falling on a photo-electric mechanism—the retina of the eye.

In the response of the eye, conceived as a photo-electric effect, there is nothing strange, as man-made photo-electric cells exhibit even better vision than is manifested by the human eye. These non-living automatons can initiate and execute many kinds of work, just as the eyes of animals initiate and through the release of electric and chemical energy cause to be executed muscular action, glandular work, and mental processes. With respect to the nature of the chemical reaction of the retina and in the brain and in the conducting nerves and in the muscles, there is now the following evidence which tends to show that this reaction is not a simple oxidation of carbon compounds.

(1) The energy derived from burning of a carbohydrate or other compound does not account for all the calories produced.

(2) Tashiro demonstrated that ammonia is liberated during the passage of an action current along a nerve. Emden has demonstrated that ammonia is produced during muscular contraction. Dr. Telkes has shown that during the growth and metabolic activity of the autosynthetic cells ammonia is produced.

(3) In our experiments on the formation and activity of autosynthetic cells made in collaboration with Dr. Telkes and Miss Rowland, we found that protein, which may be considered as a fixed nitrogen compound, is the only food that the autosynthetic cell can utilize.

(4) Lastly, and one would think conclusively, the contraction of a muscle can be executed normally, generating normal energy,

and producing normal amounts of carbon dioxid, water, and ammonia, when enzymes, catalysts, and oxygen itself are excluded, just as nitrocellulose, nitroglycerine and gunpowder can be exploded in the absence of a catalyst or of oxygen.

All of these nitro-carbon groups have incorporated within themselves the required amount of oxygen for complete oxidation. The nitrogen fraction, at the instant its sensitive bond is broken, releases enough heat or other energy to oxidize the carbon group. The oxidation itself of carbon compounds is the same when it is not combined with the bound nitrogen group but in the carbon compounds with which the bound nitrogen group is combined, as in protoplasm and nitro-explosives, an exact amount of oxygen is present, and, therefore, no free oxygen is required for combustion. Oxidation is then instantaneous. Gunpowder, nitrocellulose, nitroglycerine, T.N.T., do not require free oxygen for explosion; they explode completely while they are encased in shells. Likewise bound nitrogen compounds such as the proteins in muscle may be supposed to explode or oxidize without the presence of free oxygen.

On the other hand, muscle does consume free oxygen in the process of building up its nitrogen compound. Nitrocellulose and gunpowder use oxygen in chemical combination in the process of being built up from the chemical units which make up the explosive. This bound nitrogen group is incorporated in the nitric acid whose oxygen was taken up from the air in the formation of nitrogen peroxide by lightning. Nitric acid carries this bound oxygen into potassium nitrate, and potassium nitrate carries the bound oxygen equally well into protoplasm on the one hand, and into nitro-explosives on the other. Both the proteins and nitroglycerine can, therefore, become oxidized by using the oxygen present in chemical bonds and immediately available, thus executing a definite instantaneous release of energy. One would not expect the all-or-none law of muscle contraction or nerve stimulation to result from the oxidation of free glycogen, nor would one expect free glycogen to be instantly and completely oxidized in the process of nerve conduction or muscle contraction. If free glycogen were in a state in which it could thus be completely and instantaneously oxidized, one might expect the entire reserve supply in the animal to be burned up in continuity as in the case of gasoline and ether.

The only way in which one can suppose that minute amounts of glycogen, or of gasoline, can be burned without conflagration,

would be by the existence of mechanisms in protoplasm analogous to cylinders in a combustion engine. No such mechanism in protoplasm has as yet been described. One would not expect glycogen to burn violently in an electrolytic solution, as in animal tissue, whereas fixed nitrogen compounds analogous to protein, namely, nitrocellulose, are combustible in water provided the fulminate is dry. The end plate joining the nerve and the muscle may well be the dry fulminate.

AUTOSYNTHETIC CELLS

In our attack upon this problem we finally succeeded in setting up a model of a living cell. This model has yielded unique information.

By the use of selective stains, we know that the nucleus and the cytoplasm of cells bear opposite signs of charge. In living protoplasm we know that there are innumerable electric currents, that there are semipermeable films that surround the cells, the nuclei, and the units within the cells, each film separating electrolytic solutions of different concentrations on the opposite sides. Everywhere we see evidence of bipolar arrangements. Especially significant is the fact, as Keller has shown, that the male and the female sex cells bear opposite signs of charge, hence attract each other and form active, growing, dividing cells, whereas neither sex cell alone can grow and divide.

We know that growth and function alike depend upon energy. Therefore, as function increases, there is correspondingly less energy for growth and when the cells of the animal are completely differentiated, no energy is left for growth. Therefore, we reasoned that if we could get rid of the mechanism in adult cells that uses energy for function, we would have left only the mechanism for growth which would correspond roughly to a cancer cell. Accordingly, in collaboration with Dr. Telkes and Miss Rowland, brains of animals and of man were separated into a lipoid fraction and a protein fraction. The protein fraction bears a positive sign of charge; the lipoid a negative sign of charge. Therefore, we expect that when mixed together these two fractions would attract each other, an electric strain would be established, and organization analogous to that which occur when the sex cells come together should take place.

This strange expectation was realized in the immediate formation of cells which when observed under the microscope showed a

nucleus and a cytoplasm, films surrounding not only the cell but also the nucleus, and beautiful cilia. These cells grew and multiplied by cell division in an orthodox manner. They took eosin and hematoxaline stains as in the case of other living cells. They consumed oxygen and gave off carbon dioxid and ammonia. These autosynthetic cells remained active in cultures for eight months. They were fed exclusively with proteins, derived from the same species, as proteins are essentially carbon compounds with a bound nitrogen group incorporated in them.

These autosynthetic cells exhibit one remarkable property during their formation, detected by Dr. Glasser, namely, they emit ultraviolet radiation. They consume oxygen and give off carbon dioxid and ammonia. They respond to environmental changes—heat, drugs, electric stimulation, etc., and are destroyed by the same agents as are biologic cells. Their metabolism, like the metabolism of man and animals, is increased by thyroid secretion. In their multiplication, these autosynthetic cells obey the laws of inheritance. In brief, by every test that we could apply, these autosynthetic cells have behaved in essential particulars as protoplasm elsewhere.

SUMMARY

The gross, the ultra-microscopic, the molecular, the atomic, the electron configuration of every living thing is identified by physical constants.

Every movement of ions across the countless billions of semipermeable membranes governing chemical activities of cells is in accordance with the Nernst formula. The role of surface tension which fundamentally governs the action of cells is expressed by the mathematical equations of Einstein.

The electric conductivity, electric capacity, and electric potential of the living organism which provide an accurate measurement of the activity of cells and organs are expressed by the same mathematical formulae as in non-living systems.

The structure of protoplasm is in certain fundamental respects analogous to the structure of nitro-explosives and protoplasm is activated by like excitants. The passage of action currents is just as physical as the progressive wave along a powder trail.

Theoretically, the emission of radiant energy by living protoplasm is in wave-lengths, which vary from ultraviolet radiation

to the visible spectrum and infra-red, thus being of the value of the radiation received from the sun.

The eye obeys the law governing the activity of photo-electric cells. Since the eye is a portion of the brain projected through a hole in the skull, we may infer that the protoplasm of the brain within the skull is of like structure and obeys like physical laws and we may infer that every thought, every memory, every emotion, every act of reason obeys a mathematical equation.

Through the extra-terrestrial forces of the sun's radiance and lightning, carbon dioxid, water, and the bound nitrogen group are linked together. When this linkage breaks down, the energy of living processes is released and the chemical units return to the neutral state, ready to be used again. Therefore, may it not be that protoplasm in its construction, in its activity, in its death, and in its decay, obeys the same mathematical and physical formulae as the non-living?

RUSSIANS SAIL "IMPOSSIBLE" POLAR SEAS

The "impossible" feat of sailing around Franz Josef Land, in the North Polar regions, has been achieved by Russian explorers led by Prof. N. N. Subov. They were aided by a heat wave from Florida which started in the Gulf Stream four years ago and moving slowly northward warmed the Polar Sea this year. The voyage was made in a small motor sailing craft of only 100 tons displacement and 125 horsepower.

So closely was the trip planned, that the little boat was loaded with only 30 days' fuel and 40 days' provisions, and no winter equipment. Prof. Subov had prepared maps, and had surveyed the temperature conditions of the region for past years. He predicted that the seas northeast of Franz Josef Land and towards Novaya Zemlya would be found free of ice, owing to the fact that a large volume of warm water from the Gulf Stream has been moving for four years slowly northward, and has had a marked effect on icebergs and sea temperatures along its route.

So strong was Prof. Subov's confidence that he could travel around Franz Josef Land on the crest of this warm wave this year, that he refused to turn back when confronted by a great icepack blockade east of Graham Bell Island. Warmer water must be present farther to the northeast, he was convinced. And moving in that direction, 25 miles, a passage to the south was found. The boat had a narrow escape on one occasion, being caught in an ice pack which nearly closed upon it, but the wind changed and opened several waterways through which the craft made its escape.

September 20, thirty-four days after the little boat sailed from its starting point, Murmansk, it was back there again. Its fuel supply was down to a mere two-hour reserve. The food stores had been eked out by two white bears, shot toward the latter part of the voyage.—*Science Service.*

SCIENCE—TRUTH OR PROPAGANDA*

By Otis W. Caldwell
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At a meeting of an advertisers' association, a commercial propagandist gave an address on the topic, "Creative Waste, the thing needed to return Prosperity." He urged a campaign against people's habits of repairing used articles. Shoes and stockings should be thrown away, not mended. An out-of-date radio should be discarded and a better one purchased. Books should not be rebound or resold, but new ones bought. The family automobile, still good for service but noisy, should be demolished, and its place taken by a newer design with free-wheeling. The speaker urged that propaganda be distributed against the frugal habit of saving and repairing articles of proved service in order that respectability should be associated with the constant purchase of new goods. It was claimed that vigorous nation-wide propaganda regarding such standards of respectability would increase the purchase of new goods, would provide employment for those now idle, would keep wages high, and would provide surplus funds for entertainment during the leisure made available through the 40 hour working-week. The speaker did not explain the source of the funds with which to make the new purchases to supplant the articles to be destroyed.

It is the business of new truth to find its way into improved machines and materials, and into improved human practices. The 79 major inventions of the world made since Watt's steam engine appeared in 1775, are some of the material exponents of the changes produced by scientific truth. Society has been reformed during the period since 1775 because, through useful propaganda, society has been led to change its former life in terms of new truth. Truth and helpful propaganda are not antagonistic to one another. Indeed, organized agencies for proper distribution of knowledge are indispensable. Education is one of those organized agencies. Doubtless the "obligation to distribute knowledge" is equal in importance to the obligation to search for new truth. There can be no reasonable controversy against the research man's hunt for new knowledge, nor against

* An address delivered at the Annual Meeting of the Central Association of Science and Mathematics Teachers, Cleveland, November, 25, 1932.

the publicist's eloquence about the constantly new world made available by new truth. We are now in great need of the right sort of a campaign not so much to teach the industrial uses of new truth, but rather the social services requisite for a society which has been so changed by scientific knowledge.

Those in charge of education are supposed to possess advanced attainments and tested experience which make it possible for them to guide others. It is the business of science teachers, and others, to propagate truthful ideas and helpful habits, and to restrict or inhibit harmful or useless ideas and habits. The extension of useful truth and of tested habits is one of the chief objects of good educational propaganda. Education is man's outstanding creation by means of which to improve himself. By constantly setting forward his ideals, testing them experimentally, then when proved, educating the masses toward these ideals, the race can continue to educate itself.

It thus appears clear that if the purposes of education are taken seriously, we may contribute to those purposes best by increasing the use of scientifically determined procedures in education. There are persons who do not agree to this statement. The relative places of the philosophic and scientific points of view of education are still in controversy. Of course we need a philosophy of education, but we think it must be a philosophy made increasingly definite by the results of scientific study. We still have too many so-called leaders who advocate a larger place for philosophy in the sense that they wish to theorize about education, untrammeled by exact truth as discovered by science. Flitting about on the wings of philosophy does not prove helpful to a teacher who must guide the plodding steps of pupils who need to go steadily in the direction which established facts have proved desirable. Do you recall the reply so often made when some propagandic philosopher is saving mankind by his well-spun schemes, and when some experienced teacher of children asks how the scheme would work in doing this or that in the commonplace tasks of the school-day's work? The philosopher replies, "Those are mere details to be worked out by those of you who sense my philosophy and go out to use it in your work." He may be quite sincere in believing he has answered the question, though his nebulous vocabulary often serves only to confuse the inquiring teacher. He "integrates his personality" as some one has said, and thus obscures whatever central truth there is about which the integration is supposed to occur.

In a recent book review America's leading educational reviewer says:

"Philosophy settles in two hours the most important question and publishes the result to the world. Philosophy hurries to its sure conclusions. Science procrastinates its decisions. . . . Philosophy is the best method for the expeditious selection of makeshifts. It is the great narcotic, the soothing syrup for author and readers, even when a gadfly is most needed. Problems demanding immediate answers before adequate investigation can be made will always be with us. We shall always need philosophy . . ."

"Education must have the scientist if only to save its practitioners from the defenseless attitude of the advocate who can establish nothing, prove nothing, defend nothing, except by appeal to some authority, eminent only in vigor of expressing opinion. We must have the results of experiment and research if only to know whether adopted objectives are possible of attainment."—(*School and Society*, 1932.)

The preceding general statements about truth and propaganda seem clear and are likely to have fairly wide approval. But it we become more specific, difficulties are encountered. The easy way always is to avoid being specific. However, it is specific cases with which individuals deal. Principles do not operate except through specific situations. Indeed, we often do not truly sense a principle except when it is seen in specific situations.

Pertinent illustration recurs often during legislative sessions, when well-meaning but misguided people launch their propagandic attacks against the use of animals in medical schools and other worthy laboratories. False pictures of animal suffering and unsupported claims of torture are sent out in this campaign. Even a cursory study of what the human race has gained quite offsets the meagre arguments of those who spread the propaganda. They overlook certain notable facts; that such animals are usually the hungry surplus of nature's everlasting overproduction; that the animals do not suffer but are usually more comfortable than they would probably otherwise be, and when in use are made insensitive to pain; that the gains are immeasurably large in relieving human disease and suffering; that the same amount of solicitude and affection if bestowed normally upon human children would do great good instead of inhibiting human progress.

In our so-called courses of instruction in education it sometimes appears that we are trying to "sell our goods," overcome "sales resistance," instead of trying to present truth so that the learner will incorporate it into his own thought, and thus make

it a working possession of his own. During the past year, an experience drew the lines sharply between mere propaganda, and truth-teaching. A student of science teaching who has some years of teaching experience, asked advice. He reported that the class of which he was a member had been indoctrinated for a week in the particular points of view of the instructor. The second test of the course was then given. Preceding the test, the instructor said: "In checking the many points of this test, answer as we have taught you. If you do not agree with us you can add to your answers the letters B.I.d.n.t.s., meaning "But I do not think so." However, you will be scored in terms of what we have told you." The student in question had received a low score on a preceding test. He decided, as he said, in subsequent tests to "play the game according to the rules." Later at the close of the course he reported that his final score was as high as was given in the class. It may be asked whether his score could have been recorded in diplomacy, and not in science teaching.

Some of our National Yearbooks should not pass unnoticed by those who believe in an objective guidance in education. In its earlier days the Yearbook was intended to be a compendium of objective data and of sound experience in use of subjects of study in education. That intention may still exist. But the common procedure in preparing such Yearbooks is well known. Many of us have served on such committees and have contributed our parts to the situation under discussion. Indeed, the chairman and possibly one or two others are often forced to put themselves into their reports far more than they intended or wished to do. The committee must have a report and the chairman is the responsible member. Such is the nature of committee work. No wonder that such reports can be predicted in their final nature when it is known who constitute the committee. But instead of my own comments let me quote again from the inimitable reviewer, a school superintendent, not a science teacher. He says:

"Is there any correlation between the truth and the self-assurance, vigor, and the beauty of the verbal bouquets with which ideas are voiced by the committee? The outcome of committee reports is an evidence that the atmosphere of desire to 'sell' the propaganda has permeated the deliberations. The larger the committee and the nearer to reigning authority, the more does it tend to degenerate into a selling agency before it knows that what it has made is a good purchase. The committee report is a stabi-

lizing agency, not a gadfly stinging contented school-folk to new efforts to improve and to discover new truth.

"Insomuch as progress does not come in this way but through rebellion, difference, and trying out new things alone, it is not hard to see how a grand, unanimous report, if, as common, it is a compromise made up of untested opinions, may serve to retard education in proportion to the number of school people that take it for a guide."

The American tendency in education to exploit one's own thinking rather than to seek objective truth by experimental methods is still too common. Experimental methods are very slow and cannot be otherwise, and educational leaders are in a hurry to lead. However, slow progress may be the most rapid, when we think of things that endure.

In the November *Harpers Magazine* there is an interesting educational article entitled, "Study Abroad." Its main thesis deals with how some of our American college and school men spend their time abroad, and what we do about it when they return. One quotation touches our present topic:

"Steadily the value of the academic degree declines, with the creation of regiments of Bachelors, Masters, and Doctors who have earned their honors by writing theses on topics such as Administration Problems of the High School Cafeteria, and An Analysis of Paring Knives in Terms of Time and Material Wastes in Paring Potatoes. At the door of . . . the teachers college, may be laid the blame for teachers of science who know no science, since they have spent their time supposedly learning the method of teaching it. In the name of service and of practical training and of good will toward men, a price has been set upon balderdash." (*Harpers Magazine*, "Study Abroad," by Olaf Axelgaard (Pseudonym) 1932.)

All of us engaged in science education must feel embarrassment that in the name of science, things have been done which make it possible for honest students of American tendencies to cite such occurrences as basis of their criticism. They have abundant evidence of this sort. Surely there is great need for belief in science for the sake of its real truth, not for its possibilities in indoctrination for personal purposes. Possibly our needs are for more real science by those studying the problems of science teaching. Would it not help if more of those who train science teachers would take their own Master and Doctorate training in science subjects instead of in education?

There is large educational demand for new scientific knowledge both in problems of subject matter and ways of doing things. But scientific experiments, slowly as they develop, may prove to be non-productive, and the chief good that comes from

some of them is in showing what should not be incorporated into school procedures. In this negative way those experiments may have high value. We surely do not expect all experiments to produce positive results. Some of these experiments, after years of careful trial, produce tested contributions of value, which may then find their way into the regular day's work. For example, it took four years for the research men and their cooperating high school teachers to produce experimentally-tested results showing how science teachers may correct pupil attitudes regarding superstitions and other unfounded beliefs. Even so, the results of those four years deal with but a small number of superstitions and with but two subjects of study. It will take many years to extend such experiments into several subjects of study and to include the hundreds of unfounded ideas now common in people's beliefs. Such experimentally proved advances must find their way into printed materials for pupil use, and into the convictions and practices of teachers. They will find their way because of the established evidence presented, not because of fervid personal propaganda by those who make the experiments. Educators who must hurry to reorganize things, usually cannot wait for the results of scientific studies.

It has been shown that many superstitions and other unfounded beliefs are perpetuated by propaganda, though not always intentionally. Maller and Lundeen (*Sources of Superstitious Beliefs*, 1932) in their investigations found that "friends" rank highest and "home" next to highest in fostering superstitions; also that observation, books, newspapers, school and church combined under the heading of "educational" rank highest as factors in correcting superstitions. That is, guided observation and good books and newspapers are highly important in correcting undesirable attitudes and in establishing those that are desirable. Since attitudes have so much to do in determining human behavior, it seems highly important to make direct effort to develop desirable attitudes. There are persons who argue that direct teaching does not produce attitudes but that the desired attitudes will result as by-products from the teaching of facts and principles. This sounds a good deal like the footless claims made 40 years ago when the "Committee of Ten" told us that exact science studies would make human beings scientific in their attitudes. It seems surprising that the 31st Yearbook of the National Society for the Study of Educa-

tion, 1932, still claims that attitudes are by-products of science teaching. The following is quoted: "Attitudes are also necessarily concomitant with the understanding of ideas and the understanding of methods. In their origins, attitudes are based upon understanding (or lack of it), and they are the reaction of a personality to learning experiences. Desirable attitudes, that is, attitudes that are consistent with truth, are the ones that are formed as a result of satisfactory experience in learning." This assuring statement is not accompanied by any evidence that its claims are proved. While the meaning of this statement is not entirely clear, I understand it to mean that attitudes consistent with truth will be absorbed or developed while facts and principles are being mastered.

Attitudes are now thought to be as specific as are other objectives and like others they must be directly sought by specific efforts if they are to be developed. If teachers could be clear just which attitudes would be most useful in advancing human welfare, and could know just what teaching would produce those attitudes, we might incorporate this highly important element into the subjects of study we now have. It is only through such specific efforts that we can relieve people of harmful reactions and establish those that will be helpful. It is very much easier to teach facts and principles, which we all agree should be taught, than it is to teach helpful attitudes and to correct false attitudes.

Miss Florence Weller has done a piece of research, as yet not published, based upon experiments with 450 sixth grade pupils. She finds that specific instruction produces changed attitudes. Her experimental pupil-groups all show statistically significant results in gain of attitudes regarding the points used in the experiment. As illustration of her work she says: "We may teach the life history of a muskrat and its uses to man but unless we teach that muskrats are not weather prophets and that it is a fallacy that they build their houses higher when there is to be a severe winter, children do not apply their knowledge." She further concludes that "science provides the means of developing desirable attitudes and skills in problem solving if attention is focused on this aim." No one has yet reported research to prove how long or in what ways the desirable changes in attitudes will persist. No reason is known to show that good attitudes will be any less persistent than undesirable attitudes.

Pure science also occasionally witnesses the spectacle of ques-

tionable propaganda by a scientific worker. The obligation to distribute tested knowledge is sometimes shifted to a personal campaign to convince the public of the magnitude of the particular worker's contribution. A fervid and contentious popular address, or perhaps the more quiet and more insidious correspondence campaign about a question which should really be determined by scientific evidence is in itself an evidence that we still have far to go before we can claim that we are a scientific people. Truly, the products of science, her inventions, improved health, advocacy of guidance by truth, and her new reasons and foundations for moral living have far outrun human adjustments. Possibly our greatest need is not more universal assent to the findings of science but assimilation of science into our habits of action.

Our whole American educational program is an illustration of an essentially good use of propaganda. From a few selected pupils in school, we have grown until everybody's children can and do go to school. Nothing equalling it has occurred in the world in all human history. We have built and extended the whole plan. Can we learn the answer to specific problems within the plan rapidly enough to permit the plan to do what it was designed to do?

ARCHAELOGISTS TUNNEL INTO WORLD'S LARGEST PYRAMID

Mexican archaeologists who are exploring the heart of the world's largest pyramid located at Cholula have unearthed numerous stone stairways which lead to a 130-foot paved platform.

The adobe pyramid is now honeycombed by some 1,000 feet of tunnels made by the archaeologists. The tunnels are enabling the explorers to reveal the interior complex of structures without disturbing the Spanish colonial church which now stands on top.

One stairway which has been found is over 160 feet wide, and is the widest stairway in American archaeology. It appears to have been four times rebuilt. Its destination has not yet been revealed by the excavations.

The great pyramid is being excavated under the direction of the engineer Emilio Cuevas of the Mexican Direction of Archaeology.—*Science Service.*

PRESENT AT OWN CENTENARY

The unique celebration of the centenary of a living scientist has just been held at the French Academy of Medicine. This scientists is Dr. Alexandre Gueniot, obstetrician, surgeon, author and former president of the Academy. Dr. Gueniot's father was so depressed by the post-war hard times and changing social customs of the early nineteenth century that he gloomily wagered, the day of his son's birth, that the little boy would certainly not live to be 100 years old.

LINEAR AND QUADRATIC STRAIGHT AND SQUARE*

By Louis C. Karpinski
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No accident of curcumstance has determined the designation of fundamental ethical values by the words straight and square. The right line and the geometric figure with four equal sides and four right angles, "four-square," stand as symbols of proper ways of thought and of life. The fundamentals of number and of form are as basic in the evolution of intelligence as music and literature, as art and religion.

The stone or the Newtonian apple that falls has a velocity given by a linear function of the time and equally the vertical velocity of a bullet shot from a gun; in each instance the height attained is a quadratic function of t. Given a bullet shot vertically using a U. S. Army revolver the height attained is given by the formula $h=800t-16t^2$ and the solution of this equation gives in the discriminant the value for h which is the maximum height attained. The linear function $v=800-32t$ when equaled to zero gives the time at which the maximum height is attained.

Heat a metal bar and the varying length is given as a linear function of the temperature or measure the velocity of sound in air of different temperatures and you find a linear function of the temperature. Of course there are physical limitations but these are the first approximations. Ordinary interpolation assumes a straight line, linear relationship.

Look around this auditorium and you see that it is built to a quadratic curve, the parabola $y^2=4ax$; so is the automobile headlight and to this curve falls naturally the cable holding a suspension bridge. The quadratic relationship confronts us in many situations.

Commonly and quite properly we associate Descartes and the development of the analytic geometry with the correspondence of a first degree equation in two unknowns and a straight line. However that great philosopher would have been the first to admit that back of this correspondence lie fundamental connections between numbers and form, algebra and geometry, which are only revealed and not at all created by the Cartesian symbolism.

* An address delivered at the Annual Meeting of the Central Association of Science and Mathematics Teachers, Cleveland, November 24, 1932.

Fifty years ago in Egyptian papyri found at Kahun it was ascertained that two thousand years ago an Egyptian proposed the problem to divide an area of 100 square units into two squares whose sides have to each other the ratio 3 to 4. This leads to a Pythagorean triad, $6^2+8^2=10^2$, that is to the 3, 4, 5 right triangle relationship, as the solution of the pair of simultaneous quadratic equations. About sixty years ago Babylonian tablets were found giving tables of squares and cubes, as well as other tablets with arithmetic and geometric series. These more or less isolated documents in connection with related problems in that fundamental mathematical document, the Ahmes papyrus, led me sixteen years ago to write an article, Algebraical Developments of the Egyptians and Babylonians. In 1915 in Chicago I gave before the Mathematical Section of this Association an illustrated talk upon the history of algebra, indicating the part of the Egyptians and Babylonians in the development of algebraic ideas. In 1919 I published in Scientia in French a more detailed article on The Origin and Development of Algebra, later translated into English and appearing in your official organ. In these articles I stressed the probability of new light through new documents.

In 1917 a Russian named Touraeff published in French in a journal called Ancient Egypt the account of an Egyptian papyrus in Moscow giving a formula for the volume of a truncated pyramid and giving problems also involving the area of a rectangle and the ratio of the sides of the same. This document has now been published in its entirety by V. Struve, revealing also the fact that the ancient Egyptians knew the quadratic nature of the formula for the area of the surface of a hemi-sphere.

Within two years Babylonian tablets have been interpreted revealing that in ancient Babylon the solution of the quadratic equation was fully achieved. One type of problem solved involves the computations of chords in a circle, an achievement connected with the known remarkable development of scientific astronomy among the Babylonians; other quadratic equations arise and are treated in connection with the area and linear functions of the sides of right triangles.

Here we have in Babylon as in Egypt the earliest algebraic problems devised by the mind of man evolved from geometric considerations, involving also extensive arithmetic computation and trigonometric ideas. Possibly it does not become me to say, being an author of a somewhat unsuccessful Unified Mathe-

matics, that the ancient Babylonians believed in Unified Mathematics.

The progress and development of these algebraic-geometric ideas in the civilizations of the Greeks, the Hindus, the Arabs and the Europeans, reveals the fundamental character of the contribution of mathematics to the progress of civilization.

Some misguided students of so-called education look upon the algebra and arithmetic and geometry in the school program as an artificial imposition upon the school curriculum. This view involves abysmal ignorance of the inescapable part of mathematics in the understanding of the modern world. Engineering and commerce, and chemistry and physics are not comprehensible without a mathematical background, and even in the biological sciences and medicine, many important developments hinge upon mathematical considerations.

Another and more insidious attack upon the teaching of arithmetic and of mathematics in our schools is being made by supposedly professional professors of education who are writing textbooks on arithmetic and mathematics for our schools. Without any real knowledge of mathematics, without any recent experience in the class room in teaching mathematics, so-called or self-styled experts presume to write textbooks on mathematics.

There is a veritable epidemic of these textbooks in mathematics by these pseudo-experts who wish to exploit the schools for their private gain. Were a man to write a text book on children's diseases based upon no study of children and no contact with children having the diseases that man would doubtless be put in an insane asylum. Because mathematics operates upon the mind an ignorant man may with impunity write a textbook for children which may be adopted even by state boards controlling the textbooks for a whole state.

Why are such textbooks adopted? Every one knows and hardly one dares to say, that it is largely because some of these authors have power either in national educational organizations to place complacent and obliging superintendents upon important committees or have other crass ways of rewarding the faithful such a recommendation for promotion. *At one teachers' college I am reliably informed that at one time no less than twelve members of that teachers college staff were writing textbooks on arithmetic.* Under oath, if necessary, I would testify that ten, at least of these men are incompetent. This is to the best of my

knowledge and belief, based upon over thirty years devoted largely to the study of mathematics and the teaching of mathematics. At this same teachers college there were at this time several members of state boards on textbooks as candidates for the doctor's degree. Some of these men got their doctorates and doubtless some of the corresponding textbooks were adopted.

I have heard it said that the textbook situation is improving. Possibly! In a large city not far from here the Republican Party (before the recent election) acting through the City Superintendent adopted, without any vote of the teachers concerned, one of these textbooks prepared, or at least sponsored, by a man fundamentally ignorant of mathematics.

Gentlemen, since these quasi-experts succeed in having their ignorance in mathematics rewarded financially, you may count upon it that the next attempt will be to write the textbooks in physics, in chemistry, in biology, and in the other sciences. To date reading and arithmetic, since any fool can obviously write a textbook in these fields, have succumbed to the grasping avarice of some of those who profess to teach education.

Many of these educational experts are quacks advertising themselves as able to cure every educational ill. Patent medicine claims have nothing on these pseudo-experts. They can revise your whole school system; they can "fix" your school buildings and the new building plans (for a fat fee) and the word "fix" is right; they can appoint you superintendents, directors of this and that, etc.; and these gentlemen (so to speak) can also write you textbooks in spelling, reading, arithmetic or what have you?

Certainly modern psychology and true research in education have made it evident that only actual experience in any field renders a person competent in that field. Certainly one could reasonably assume that universities and even teachers' colleges are committed to this point of view. A few afternoons devoted to a hasty review of elementary arithmetic and algebra has apparently made several professors of education competent to write textbooks to be used by the primary children, by the children of the fourth, fifth and sixth grades, and even by the junior and senior high school children now doing real work in mathematics. If this be not a travesty upon science and upon education what would be? Were it true that such a preparation would suffice for the serious task of writing proper textbooks in arithmetic then no school of education need exist. Proper textbooks

can only grow out of classroom experience by persons qualified to profit by that experience.

This irrational development which we have been discussing is essentially crooked, certainly not straight and square.

But let us, after this digression, return to the linear and quadratic, to the straight line and the circle. In machinery largely the motions are compositions of translations and rotations and in consequence the equations of the straight line and the circle play a fundamental part in the analysis of the motion.

In machinery as an element in the progress of civilization a fundamental consideration is that the same operation is repeated over and over, making possible, as Mr. Henry Ford has so well demonstrated, quantity production. Some people are not conscious of the fact that the happening over and over again is characteristic of much of our experience. The heart beat, the pulse, and the breath are obvious recurrences but quite as much recurrent wave motion is involved in speech phenomena (independent of sex), in the functioning of the ear and the eye and other organs of the body. These recurrent physical phenomena can be geometrically analyzed in terms of the sine (and cosine) curve.

The algebra and analysis enter, of course, in the analytical consideration of such phenomena. However it is not so obvious that here is where the recurrent nature of our friend the square root of negative one enters. By definition of a new algebraic unit $i^2 = -1$, whence $i^3 = -i$, $i^4 = +1$, $i^5 = i$, $i^6 = -1$, $i^7 = -i$, $i^8 = +1$ and so on recurring. To those who have not recently studied the complex numbers, $x+yi$, it must suffice if I state that with the ordinary Cartesian co-ordinates such a number is represented by either the point $P(x, y)$ or by the vector OP having magnitude and direction indicated by the line from the origin to the point (x, y). Two such numbers are added geometrically by the parallelogram law, the "parallelogram of forces," since each is represented by a vector. It is because of this that the physicist finds these numbers so useful despite that they were evolved from purely theoretical and logical considerations by mathematicians.

Steinmetz has shown that theoretical considerations of the electrical current are made relatively clear by the use of the complex numbers, due to the vibratory, cyclical character of electric phenomena. The mathematical considerations have again and again not only explained the observed phenomena

but have contributed new phenomena suggested by the algebraic equations. Notably Maxwell's equations in the hands of Herz and a host of others led to the discovery of the wireless and the radio.

The geometrician finds that the regular polygon of five sides, constructible with ruler and compasses, corresponds to an algebraic equation solvable in terms of quadratic irrationalities. That great genius Johann Carl Friedrich Gauss (he was entitled to four names) showed also that the equation $x^{17}-1=0$ can be solved by a series of quadratic equations. Gauss, then a youth of nineteen, showed that this solution corresponds to the fact that a regular polygon of 17 sides can be inscribed in a circle using only ruler and compasses.

Before Gauss the Arabs had arrived by other algebraic methods at the fact that the regular polygons of seven and nine sides reduce algebraically to cubic equations. Only quite recently were mathematicians able to prove by methods involving necessarily the complex numbers that these cubics are not reducible to quadratics and that the regular seven-gon and the regular nine-gon, as well as the trisection of an angle, are not possible in general with ruler and compasses.

No mathematician wishes to exalt the mathematics as more worthy of study than plant life or animal life or physical and chemical phenomena, nor does the mathematician try to cast any doubt upon the desirability of the study of art, including literature and music and the drama. But emphatically the mathematician wishes it made clear that ideas are fundamental, that the line and the circle are with us to be understood, and that no one can pretend to any serious comprehension of the universe in which we live without understanding some algebra and geometry—the linear and the quadratic, the straight and the square.

THE COMPERS CREED

What does labor want? It wants the earth and the fullness thereof. There is nothing too precious, there is nothing too beautiful, too lofty, too ennobling, unless it is within the scope and comprehension of labor's aspirations and wants. We want more school houses and fewer jails, more books and fewer arsenals, more learning and less vice, more constant work and less crime, more leisure and less greed, more justice and less revenge—in fact, more of the opportunities to cultivate our better natures, to make manhood more noble, and womanhood more beautiful, and childhood more happy and bright.

THE SYSTEMATIC DEVELOPMENT OF LEARNING UNITS IN GENERAL SCIENCE*

By John C. Mayfield
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III. Trial and Revision

The preceding sections of this article, published in March, 1932, outlined a method of selecting general science units and of organizing teaching materials. The first set of study guides and tests for a unit seldom proves entirely satisfactory, no matter how carefully it may have been prepared. Only by actual use and careful checking of the results can all the weaknesses be detected. During the trial, the alert teacher cannot fail to observe common troubles which are due to the wording and form of questions and problems. He will see which exercises obviously fail to require the desired knowledge for their solution, which ones are laborious to correct, which ones are answered by copying text material, and which ones are so difficult as to result in a waste of time. It is almost superfluous to add that notes of such observations are made and used. Otherwise the defects will have been forgotten when the time comes to teach the same material again and the inefficient exercises will not be revised nor replaced.

For an objective indication of difficulty the number of trials made on each exercise of the unit, "Heating and Ventilating Our Buildings," is tabulated in Table I. Table II, which is derived from Table I, indicates clearly the per cent of erroneous attempts on each exercise so that the relative difficulty of the individual exercises can be seen. Examination of the per cent line shows that Exercises 4 and 7 form one group in which close to half of all attempts were returned for correction. A second group consists of those exercises on which about 40 per cent were incorrect and includes Exercises 2, 3, and 8. Exercises 1 and 5 show about 30 per cent of error while Exercise 6 is not far from ten per cent. Whether it be a desirable feature or not the difficulty of the exercises in this Guide for Study was nicely graduated.

It would seem that Exercises 4 and 7 should be carefully examined to see if there is not a waste of effort for, on the average,

* Parts I and II of this article appeared in Vol. XXXII, page 250, March 1932.

TABLE I

NUMBER OF ATTEMPTS REQUIRED FOR SUCCESSFUL COMPLETION OF THE STUDY EXERCISES ON "HEATING AND VENTILATING OUR BUILDINGS"

Number of Attempts Required	Study Exercise							
	1	2	3	4	5	6	7	8
None (Pupils excused)	33	3	2	3	3	4	2	4
1	45	41	52	32	62	87	30	50
2	18	48	38	40	33	9	40	35
3	4	7	6	20	2		16	10
4		0	2	5			9	1
5		1					2	
6							1	
Total Pupils	100	100	100	100	100	100	100	100

TABLE II

RELATIVE DIFFICULTY OF STUDY EXERCISES ON "HEATING AND VENTILATING OUR BUILDINGS," AS DETERMINED BY PER CENT OF ATTEMPTS CONTAINING SCIENCE ERRORS

Exercise No.	1	2	3	4	5	6	7	8
Number of Pupils Writing the Exercise	67	97	98	97	97	96	98	96
Total Number of Attempts	93	163	154	192	134	105	209	154
Number of Attempts in Error	26	66	56	95	37	9	111	58
Per Cent of Attempts in Error	28.0	40.5	36.4	49.5	27.6	8.6	53.1	37.7
Order of Difficulty*	3	6	4	7	2	1	8	7

* The difficulty increases from 1 to 8.

each paper had to be reworked once. Such mechanical calculation should not be used alone to decide which exercises are wasteful of time and effort and should be discarded. It may be that an exercise which requires a large number of corrections embodies a difficult but important point and need only be revised or stated in a different form to present the problem more effectively.

Whenever possible, then, the final check on the results of the teaching is a careful analysis of the written work of the pupils, principally the study exercises and tests. A record is made of all information which will be helpful in meeting the needs of another year's pupils. These data include: (1) errors in the interpretation of exercises, (2) errors in the solution of exercises, (3) errors in science which do not directly affect the correctness of the solutions, (4) important terms which are frequently misspelled, and (5) characteristic pupil reactions to the material of the unit. The assimilative or study exercises examined are limited to first attempts in order to prevent the repeated occurrence of any one pupil's difficulties in the record. This is somewhat inaccurate in that some pupils who make an error often make a characteristic second and third mistake, arriving at the truth only when they have found that a whole series of ideas is wrong.

A careful study of the results of teaching the unit, "Heating and Ventilating Our Buildings," is presented below. For each exercise there are given in order, the directions, the idea expected in the answer, the relative difficulty from Table II with some details of the number of corrections required, the specific difficulties found in the pupils' papers and the frequency of each, a comment on the results of teaching the exercise, and finally, recommendations for so amending or replacing the exercise as to make the teaching more effective and economical.

EXERCISE 1

"When one builds a fire he places the easily kindled material at the bottom and then puts on larger and larger pieces. He then lights a match and starts the kindling to burning. In a little while there is a great fire which gives off much more heat than was given off by the match. Where did this larger amount of heat come from?"

Idea expected in the answer.—The larger amount of heat came from the burning, or oxidation, of the fuel.

Difficulty.—From the percentage of papers which required correction this exercise is one of the least difficult of the series, being third of the eight when ranked in order of increasing difficulty. One-third of all the pupils were released from the exercise on the basis of the pretest, forty-five of the papers handed in were approved on first trial, eighteen had to be corrected once and four were approved only after two corrections had been made.

Specific difficulties with illustrative quotations and frequencies.—

1. Heat attributed to more material—oxidation not stated to be the origin of the heat. "There was more material in the fire." ..... (4)
2. Pupil confused fire with heat. "The heat started in the match and was transferred to the wood." ..... (3)
3. A confused attempt to explain without the discovery of the true answer. "Because all materials that burn with a flame turn to a gas before they combine with oxygen a large amount of heat is produced." ..... (2)
4. An imperfect understanding of the nature of heat as it had been described in reading material or in the presentation of the unit. "The heat comes from the faster rubbing together of the molecules." ... (2)
5. "The energy in the wood combines with oxygen." ..... (1)
6. "The larger pieces of wood have more oxygen in them.' ..... (1)

Words commonly misspelled: *oxygen, oxidation.*

Comment.—Pupils who study this unit have, as a rule, studied "The Nature and Control of Fire," either immediately before or in an earlier course. This accounts for the large number of releases following the exploration test. Furthermore, examination of the exercise and of the typical errors indicates that much of the trouble was due to the peculiar form of the exercise and not to a lack of knowledge that heat is commonly secured from a fire. Because of the lack of need for an exercise based on the idea it seems well to omit this one entirely. The source of heat should be emphasized in the presentation and if necessary some pupils may be given special assignments.

EXERCISE 2

"List ten common instances of the transfer of heat by radiation, ten of its transfer by conduction, and ten of its transfer by convection."

Nature of responses expected.—It was intended that the lists should contain instances from the pupils' own experiences, and that they should be described with enough detail to be identified. Seldom was the exercise so interpreted by pupils and they

were only held to a list of true examples or of types of cases in which each method of transfer occurs.

Difficulty.—This exercise ranked sixth of the eight in difficulty. Three of the one hundred pupils were excused from the exercise, 41 had it approved at first attempt, 48 were required to make corrections once, seven made corrections twice, and one did not have his paper correct until the fifth trial.

Specific difficulties with their frequencies.—

A. Ideas incorrect for the exercise but not incorrect in general.
   1. Substitution of some illustration for transfer of heat. "If a book is handed from person to person that is conduction."
      (a) For radiation.....(4)
      (b) For conduction.....(7)
      (c) For convection.....(5)
   2. List of conductors given (or one conductor after another named in same situation).....(13)
   3. List of radiating objects given without accompanying situation..(4)
   4. Similar error with convection. "A candle has convection currents."".....(3)
   5. Substitution of characteristics of a material for an example of heat transfer. "Silver is the best conductor of heat." "Heat can be radiated through glass."
      (a) For radiation.....(12)
      (b) For conduction.....(9)
      (c) For convection.....(1)

B. Erroneous ideas in responses.
   1. Example placed in the wrong list of cases. "A hot-water bottle heats ones body by convection."
      (a) Example of radiation given for—
          Conduction.....(6)
          Convection.....(7)
      (b) Example of conduction given for—
          Radiation.....(9)
          Convection.....(6)
      (c) Example of convection given for—
          Radiation.....(17)
          Conduction.....(13)
   2. Conduction of fire considered conduction of heat.....(8)
   3. Conduction of electricity given for conduction of heat. "Heat is conducted along the wires to an electric toaster."".....(9)
   4. Flow of liquid in a pipe given as an example of the conduction of heat.....(3)
   5. Belief in—
      (a) The conduction of "cold".....(7)
      (b) The radiation of "cold".....(4)
   6. Belief that radiation is important in heating air directly, that is, radiant energy is readily changed to heat by the air.....(4)

7. Belief that molecules of air shoot out sidewise in radiation.....(3)
8. "There are heat molecules."..... (3)
9. Belief that radiation goes only a few feet straight out through the air..... (2)
10. Belief that there are "convection waves."..... (2)
11. Steam is a form of radiation..... (1)
12. Radiant energy goes through iron..... (1)
13. There are "currents" of radiation..... (1)
14. Molecules expand when heated..... (1)
15. Hot molecules are lighter than cool ones..... (1)
16. Energy burns..... (1)

Common misspellings: "*currant*" for *current.*
"*raidation*" for *radiation.*
"*transfered*" for *transferred.*
"*chimbly,*" etc., for *chimney.*

Comment.—Evidently the difficulties under *A* are quite largely due to a misunderstanding of the intent of the exercise, either because of its form or because of careless interpretation of the directions. The more significant difficulties in thought, observation, or interpretation of reading material listed under *B* are: (1) the apparent inability of many pupils to distinguish between the different methods of transfer after reading about them, especially in mistaking convection for either radiation or conduction; (2) the inclusion of conduction of fire, electricity, and liquids as instances of conduction of heat (although, of course, fire may be due to the conduction of heat); (3) the belief that radiation is important in heating the air directly; and (4) belief in the transfer of "cold" instead of heat. Some of the other less frequent difficulties are significant in that they occur repeatedly in work with heat.

The exercise proved unexpectedly difficult but was very effective in giving true concepts of the different methods of heat transfer. The revised form below will eliminate a large number of mistakes. However, many of the difficulties listed above under *B* were due to incomplete mastery of ideas presented in reading and discussion and would probably occur under any method of attack.

Revised exercise.—"Give ten instances of the transfer of heat by radiation that you have actually observed. Give also ten instances of conduction and ten of convection from your own experience. Try to make the instances somewhat different from each other so your lists will not be monotonous repetitions. (In case you cannot immediately think of enough examples that you

have observed you may postpone the completion of the exercise until you have had a chance to look for them in the laboratory and shop and at home.)"

EXERCISE 3

"Prove that warmer parts of fluids (gases and liquids) are pushed up by the cooler parts and do not 'rise' of their own accord as people commonly suppose. (Prepare a brief outline of your proof and have the instructor approve it before writing it out.)"

Nature of response expected.—Exercise 3 as given above was tended to eliminate the common false idea that hot air "rises" instead of being pushed up by the surrounding cooler air, by teaching the correct interpretation of the phenomenon. It was also designed to provide instruction and practice in giving evidence for statements made and especially in the use of experimental evidence for that purpose. Accordingly, a number of experiments which could be used for evidence were performed as demonstrations several days before this exercise came up for attention. The pupils were directed to take notes "for future use." When the class began work on the exercise the instructor gave a possible way of beginning the proof and suggested some of the first points which might be used. It was expected that the final report would give some supporting evidence for each point advanced in the outline approved earlier by the instructor.

Difficulty.—The number of rejected attempts on this exercise indicates that it is fourth in difficulty. Thirty-two pupils corrected their papers once, six did them over a second time and two papers were rejected three times.

Specific faults in responses with their frequencies.—

1. No evidence presented.....(13)
2. No evidence given for certain points.....(28)
   (a) That air has weight.....(22)
   (b) Air has weight whether it is hot or cold.....(18)
   (c) Air expands when heated.....(13)
   (d) Hot air is less dense than cold air.....(10)
3. Proof not carried to the assigned conclusion.....(7)
4. Statements not connected into a proof.....(5)
5. Failed to follow the outline submitted.....(1)
6. "If two flasks of air be balanced and one be heated it will rise showing that both hot and cold air have weight."....(5)
7. Careless description of experiments used for evidence.....(3)
8. "Materials are more dense when heated."....(2)

Comment.—It is believed that this exercise is valuable and effective for the purpose for which it was designed. There was much difficulty of the nature which would naturally arise when pupils have had no training of this type of writing. It would probably be better to mention in the exercise the experimental evidence which may be used. The following form of the exercise might prove useful in eliminating difficulties.

Revised exercise.—"Prove that warmer parts of fluids (gases and liquids) are pushed up by the colder parts and do not 'rise' of their own accord as people commonly suppose. To prove your point you will need to give some observation or result of experiment to show that *each* statement you make is true. Prepare a brief outline of your paper and have the instructor approve it before writing out the proof itself. Your approved outline should be handed in with the finished paper."

EXERCISE 4

"Trace the heat from its source to the air of a room through each of the devices listed under *C*, (1) above. Name the methods of transfer in each place where they occur. Thus, in explaining how the heat reaches the room from the fire in a hot-air furnace one might say, 'The heat energy is released from the fuel in the firepot by its rapid oxidation. It is transferred to the iron walls of the firepot by conduction and radiation, passes through the iron and into the air surrounding it by conduction, etc. . . .' "

Nature of response expected.—The nature of the desired response to this exercise is clearly indicated by the example given in the exercise. A correct answer would follow the heat step by step and name the method or methods of transfer in each place where they occur. (The example given in the exercise should read, "The heat energy is released from the fuel in the firepot by its rapid oxidation. It is transferred to the iron walls by radiation, conduction, and convection." Etc.)

The steps should be named approximately as given in the outline below with the methods of transfer as indicated opposite each step:

(1) Stove.
  (a) Fire to iron—radiation, conduction, convection.
  (b) Through iron—conduction.
  (c) Iron to air and room—radiation, conduction, and convection.
(2) Hot-air furnace.
  (a) and (b) as in (1).
  (c) Into air in jacket—conduction.
  (d) Furnace to room above—convection.

(3) Hot-water system.
  (a) and (b) as in (1).
  (c) Into water—conduction (principally).
  (d) Boiler to radiators—convection.
  (e) Through walls of radiators—conduction.
  (f) From radiators to air and room—radiation, conduction, and convection.
(4) Steam system.
  (Steps and methods of transfer as in (3)).

Analysis of actual responses.—In Table III are tabulated the data secured by examining the 93 papers collected from this exercise. The table makes it possible to tell what type of response was most common for each step with each device. The outstanding observations are, first, that in the case of all the heating devices, pupils more commonly fail to recognize in any way the steps from fire to iron and through the iron than any others in spite of the fact that they are illustrated in the exercise. Second, where conduction of heat through a metal occurs, the method of transfer is usually named if recognized. Third, there is a rather general failure to analyze correctly the method of transfer of heat where convection and radiation occur. Fourth, a number of pupils consider that they have traced the heat through a heating system when they have imitated an explanation found in some textbook.

Lack of experience with heating systems and the fact that convection and radiation are less evident to the senses than conduction probably account for the first three general tendencies stated. The fourth is evidence of careless thinking on the part of a certain group of pupils.

Since none of the reference books give a complete and ready-made solution for this exercise, it is believed that it effectively forces pupils to read and think about the common heating systems until they are familiar with their general layout and principles of operation. The pupils are also provided with further practice in applying their knowledge of the methods of heat transfer learned in Exercises 2 and 3.

The following form of the exercise makes the papers easier to correct and aids in clarifying the pupils' thoughts. The teacher can give much help by showing how a sectional diagram of the essential parts of a heating system facilitates the tracing of the heat.

Revised exercise.—"Trace the heat from the fire to the air and objects in a room through each of the devices listed under *C*,

TABLE III

FREQUENCY OF DIFFERENT RESPONSES IN THE TRACING OF HEAT FROM FIRE TO ROOM—STEPS AS IN THE ANALYSIS ABOVE

Device	Stove			Hot-Air Furnace				Hot-Water System						Steam System					
Step	a	b	c	a	b	c	d	a	b	c	d	e	f	a	b	c	d	e	f
Step Recognized and Methods Named	17	55	56	37	49	50	60	19	34	41	37	38	26	18	37	34	48	37	30
Step Recognized; Methods not Named*	46	11	32	18	5	18	19	31	5	24	45	13	45	23	4	35	29	7	40
Step Not Recognized	27	24	1	29	30	17	4	32	43	17	1	31	11	40	40	12	3	33	7
Explanation Substituted	2	1	1	5	5	5	5	7	7	7	7	7	7	6	6	6	6	7	7
Tracing Incomplete	1	2	3	4	4	3	5	4	4	4	3	4	4	6	6	6	7	9	9
Total	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93

* Includes failure to name, incomplete naming, and incorrect naming of methods of transfer of heat.

(1) above. Name the methods of transfer in each place where they occur. It will be best to write your exercise in the form of a table like the one below. Remember that radiant heat warms air very little in passing through it.

The Transfer of Heat From Fire to Room

Step	Method of Transfer
(1) Fireplace	
(a) ———	
(b) ———	
(2) Stove	
(a) Fire to iron of stove.....	Conduction, convection, radiation
(b) Through iron.....	Conduction
(c) Iron to air.....	Conduction
(d) Stove to distant parts of room.....	Convection
(e) Iron directly to objects....	Radiation
(3) Etc., etc.	

EXERCISE 5

"Draw carefully and label fully a simple diagram of the heating system in your home. Explain how it works. (Refer to your account in Exercise 4 if you wish.)"

Nature of response expected.—Perfect and detailed diagrams were not required. Pupils were expected to observe the heating plants in their homes and to use their textbooks for aid in interpreting what they saw. Where diagrams or parts of them were necessarily taken from books, pupils were urged to give due credit. (Many of the pupils lived in large apartment buildings and were not admitted to the boiler rooms.)

Difficulty.—As determined by the number of attempts, this exercise ranks second in difficulty. Thirty-three of the one hundred pupils were required to make corrections once and two papers were returned twice.

Types of heating systems for which diagrams were made:

Type	Percentage
One-Pipe steam.....	40
Two-Pipe steam.....	23
Hot Water.....	22
Hot Air.....	15

Nature of responses to the exercise.—

1. Wrong type of system chosen for representation—error discovered by conference. (One- and two-pipe steam and hot-water systems were confused through careless observation.).....(10)
2. Diagrams evidently not original but not credited to source.....(33)
3. Labeling incomplete.....(13)
4. Labeling lacking.....(2)
5. Explanation lacking.....(7)
6. Explanation incomplete or incorrect.....(7)

Comment.—Quite evidently three types of difficulty stood out in the responses to this exercise: (1) The pupils were not stimulated to make sufficiently careful observation of the heating systems or such parts of them as they could see; (2) to make up for incomplete observation books were used as sources of information without giving them credit; (3) there was much lack of care in the completion of the exercise by labeling and explanation. However, the exercise is useful for creating interest in home heating plants. A well planned comment at the right time has been found to increase the amount and thoroughness of observation. The following revision of the exercise has also given better results.

Revised exercise.—"Draw carefully and *label fully* a simple diagram of the heating system used in your home. *Explain* how it works. Do your best to make your diagram directly from the heating system. In case you are forced to use help from a book, give credit for it by 'Partly from Bowden,' or 'From Hodgdon,' etc."

EXERCISE 6

"Read carefully the reference in Pieper and Beauchamp, studying the diagrams and pictures, and make a list of the important points which are new to you."

Nature of response expected.—The desired response is clearly indicated by the directions. If thoughtfully done, there was no reason for a second trial on this exercise.

Difficulty of exercise.—Exercise 6 was easily the least difficult study assignment. But nine papers were returned for corrections. In each case the pupil had misinterpreted the directions.

Nature of responses to the exercise.—

A. Errors in interpretation.
   1. Exercise taken as meaning to read all references on the unit...(9)
   2. Exercise interpreted as requiring the listing of all points in the reference.....(4)

B. Points listed as being new to readers.

1. How the heating systems of large buildings work.....(60)
2. Ill effects of poor ventilation are due to three factors named in text.....(38)
3. Fresh air may be brought in through an opening back of a radiator.....(25)
4. Heating devices may also furnish ventilation.....(19)
5. Ill effects of poor ventilation are not due to too much carbon dioxide.....(17)
6. The proper indoor climate gives the heat regulating mechanism of the body little to do.....(14)
7. Windows should be opened from both top and bottom for ventilation.....(13)
8. Lack of moisture in air irritates the linings of the air passages. .....(12)
9. Ventilating devices should provide thirty cubic feet of fresh air per minute per person.....(10)
10. Hot-air furnace has a fresh-air duct leading from the outside...(10)
11. Pans of water may be used to increase the humidity of the home. .....(9)
12. The air indoors is less humid in the winter time.....(9)
13. Air for ventilation may be sprayed or washed.....(9)
14. Window boards help prevent drafts from open windows.....(8)
15. Humidity affects the rate of evaporation of perspiration.....(7)
16. Humidity in rooms is increased by the presence of people....(7)
17. The proper degree of humidity should be maintained.....(5)
18. Ill effects of poor ventilation are due to bad odors!!—(and bad odors are due to decayed teeth!). .....(5)
19. The correct room temperature is 68° to 70° F.....(4)
20. Cloth covered frames may be used in windows.....(2)
21. Meaning of humidity is the amount of moisture in the air....(1)
22. "I didn't know that a ventilator or cloth covered frame would furnish 30 cubic feet of air a minute for each person." (?).....(1)

Comment.—This exercise is plainly a device for stimulating a fairly careful reading of a given reference. It depends on a proper class attitude for its effectiveness. Just how reliable the responses are in indicating the state of the pupils' knowledge is not known. These, if taken at face value, lead to the conclusion that some pupils have not voluntarily observed the simplest things about ventilation.

Revised exercise.—Read carefully the reference *on ventilation* in Pieper and Beauchamp, studying the diagrams and pictures. Make a list of the important points which are new to you. Please do not include in your list facts you had known before reading the reference."

(*To Be Concluded*)

HIGH SCHOOL LABORATORY WORK IN PHYSICS*

By Herbert Hazel
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My subject is very prosaic. One might wax eloquent about the objectives of science teaching, but the question of the content and procedure of a laboratory course in physics is quite commonplace. Nevertheless there is, I believe, no other single phase of high school physics teaching which is so vital in determining the success of the course as is the laboratory phase. Moreover, there is no phase which has been more generally neglected by the writers of text-books and manuals and by the teachers themselves. Certainly there is no phase of the subject on which there is so much diversity of opinion. In order to better understand some of the difficulties and maladaptations in the laboratory phase of the teaching of physics, let us review very briefly some of the salient points in its historical development.

Physics as a subject of school instruction goes back to the time of the origin of universities in Western Europe during the 12th and 13th centuries. With the contributions of Galileo in the 16th century and of Newton in the 17th century, physics became a quantitative subject, and at the same time the establishment of a firm experimental basis for the study of natural phenomena aroused widespread interest in natural philosophy. During the 18th century popular lectures and demonstrations were so much in demand that courses in physics came to be offered in the colleges of America. The 19th century saw the introduction of the public high school. The first one, opened in Boston in 1821, included physics in its curriculum. No laboratory work was done, however, for about 50 years. The first university laboratory of physics was opened by the Massachusetts Institute of Technology in 1869 and this was followed in the high schools by the gradual transition of class demonstrations into individual experimentation. By 1872 physics had so progressed that it was made an entrance requirement of Harvard University. This action was soon followed by other universities. There was little uniformity, tho, either in content or procedure in the secondary schools where physics was taught.

* Read at the Chemistry-Physics Section of the Indiana State Teachers Association at Indianapolis, Oct. 20, 1932.

In 1887 A. P. Gage, physics instructor in the English High School of Boston, and one of the leaders in the introduction of laboratory work in the high school, wrote in the preface of his well-known *Introduction to Physical Science:*

> An experience of about six years in requiring individual laboratory work from my pupils has constantly tended to strengthen my conviction that in this way alone can a pupil become a master of the subjects taught. Meanwhile my views with reference to the trend which should be given to laboratory work have undergone some modifications. The tendency has been to some extent from qualitative to quantitative work. A brief statement of my method of conducting laboratory exercises may be of service to some, until their own experience has taught them better ways. As a rule the principles and laws are discussed in the class-room in preparation for subsequent laboratory work. The pupil then enters the laboratory without a textbook, receives his notebook from the teacher, goes at once to any unoccupied desk containing apparatus, reads on a mural blackboard the questions to be answered, the directions for the work to be done with apparatus, measurements to be made, etc. Having performed the necessary manipulations and made his observations, he surrenders the apparatus to another who may be ready to use it, and next occupies himself in writing up the results of his experiments in his note book.

The greatest single influence in developing laboratory work was the publication in 1886 of the Harvard Descriptive List. This list, describing 40 experiments to be performed by pupils, provided a criterion in standardizing laboratory content materials and helped to make laboratory procedure more nearly uniform. Between 1886 and 1905 the movement of standardization went too far. Syllabi from the leading universities came to be regarded more and more as ready made courses instead of as suggestive guides. More and more emphasis was put on the formal and mathematical side of the subject at the expense of the informational and experimental. Physics teaching came to aim more and more at preparation for college and less toward practical usefulness in life. The beginning of the 20th century marked the first reaction against the emphasis on the formal and disciplinary treatment of physics. This period witnessed the passing of the old dogma of formal discipline, based on the psychological fallacy that the mind is a homogeneous tool like a hatchet, which can be sharpened by mathematics, physics and Latin so that it will cut equally well in all fields. So by 1908 thinking teachers over the country began to take stock of the content and methods in vogue and attempts were made to reorganize both in the light of the new knowledge of psychology and in the light of the changed character of secondary school

population which had been growing all the while by leaps and bounds.

SCHOOL SCIENCE AND MATHEMATICS held a symposium on the purposes and organization of physics teaching in secondary schools, the results of which are published in the December 1908 and the January and February 1909 numbers of that magazine. Allow me to quote briefly significant extracts from the comments of some of the ablest participants in the symposium.

Nicholas Murray Butler, President of Columbia University:

1. Topics chosen and method pursued should be determined by the intellectual needs and interests of pupils of secondary school age. College admission tests in physics should be made to depend upon the secondary school teaching of that subject, when properly organized and conducted, and not vice versa.

2. The teacher should put out of his mind the thought that each pupil before him is aiming to become a specialist in physical science, or that the study of physics is his main interest in life. Instead of following the logical order of topics as this would present itself to an expert physicist, he should follow the psychological order as this reveals itself in the natural working of an intelligent and curious mind of secondary school age.

3. Physical science should not be presented as something fixed and definite, whose conclusions are final, but rather as a division of organized knowledge which is constantly expanding and developing and which has frequently, within historic times, corrected its conclusions in the light of later discoveries. To this end some outline of the history of physical science, and of the time and order in which its fundamental laws were discovered and developed should be given to the student. Wherever it is possible to relate the discovery or new application of a physical principle to man's other activities, this should be done in order that the student may be made to feel from the beginning the intimate relation between the laws and phenomena with which physics deals, and other human interests. In other words, the teaching of physics should be humanized.

4. As a farther step in the humanizing of physics teaching, the pupil should be brought to know something of the men whose names are epoch-marking in the history of physical science. Such names as those of Archimedes, Galileo, Newton, Kepler, Gauss, Young, Gay-Lussac, Davy, Faraday, Helmholtz, Kelvin, Torricelli, Ampere, Joule, Fresnel, Galvani, Volta, should be familiar to the student, and he should be able to tell something of whose these men were, when they lived, and what they did which causes them to be remembered in the history of science.

5. The tendency observable in many school text-books to pursue the subject into very refined and subtle inferences is to be deprecated. Taught in this way the beginner loses his sense of perspective and physics repels rather than attracts him.

6. Far too much has been made in recent years of accuracy of measurement in the teaching of elementary physics. It is much more important to throw emphasis upon the descriptive aspects of the science and to feed the growing mind with food that really interests it and helps it to grow,

than to pursue the will-o-the-wisp of training some imaginary power of habitual accuracy. Accurate measurements have their place in the teaching of elementary physics, but that place is a subordinate one.

G. Stanley Hall, President of Clark University, contributing in the same symposium, noted the futility of continuing disciplinary methods in view of the decreasing enrollment in physics and compared the situation with James Russell Lowell's eider duck farm. The proprietors of the duck farm had demonstrated chemically that nothing would make duck flesh so rapidly and so exquisitely palatable as celery. So a vast establishment was made for the business of providing celery, but, the proprietors found, to use Mr. Lowell's own expression, that "celery was about the only food the durned ducks wouldn't touch."

Hall's prescription was:

1. Use descriptive physics of the Ganot type with many experiments illustrated in cuts and in the laboratory, but with a minimum amount of mathematics.
2. Use applications of science preceding the development of the pure science involved.
3. Use the most inspiring things from the long and glorious history of physics, with biographicals of the great discoverers which are admirably calculated to fire interest which present methods stifle.

The late A. A. Michelson, after spending a long and rich life in making refined and precise measurements in physics, said:

"It is my belief that the teaching of physics in the high school might be made far more attractive as well as useful . . . and especially so for the very large majority of pupils who do not intend to pursue the subject further either for its own sake or as a preparation for scientific or technical training—if less stress were placed upon what has come to be regarded by many as its chief object, namely, the science of measurement. . . . I would therefore propose for discussion the feasibility of a plan for the teaching of physics which avoids as far as possible the use of mathematics even of the most elementary kind . . . and which gives to the science of measurement only a secondary importance.

It is of vastly greater value to know that all bodies attract each other than to know the law of inverse squares; to know that light is produced by a vibratory motion at right angles to the direction of propagation than to be able to calculate its wave-length to seven significant figures."

Prof. Robert A. Millikan made the following contribution:

"Every good first course in physics must, in my judgment, be a fairly extended survey course. It should be thorough in the sense that principles of the first order, not those of the second or third order, are clearly stated and their most direct and simple applications thoroughly understood. It should, most emphatically, not be thorough in the sense that a small num-

ber of topics are exhaustively studied, or that any particular topic is turned over and looked at from every possible point of view. . . . We realize, in short, that the purpose of a first course is to open up the field, and we should be very careful. I think, not to commit what has been perhaps the greatest mistake of the past two decades, namely, that of attempting to carry our pupils so far into the details, subtleties and refinements of the subject in the high school course that they lose sight of the woods on account of the trees."

These were the comments of 24 years ago. They are particularly applicable to laboratory work. What changes have come about in this interval? What are the conditions now?

Between 1908 and 1928 nearly every high school text written was entitled "practical physics" and the laboratory manuals were stuffed full of exercises which were supposed to make them of great practicaly utility, such as testing the tensile strength of iron and measuring the efficiency of electric motors. The content of these manuals, most of which have survived to the present time, has grown until at present the usual number of exercises (75 to 100) is so large that pupils must skip here and there thru the book in the school term of 30 to 40 weeks, leaving half the work completely discarded, and much of the remainder so hopelessly tangled up with complicated machines that simple and fundamental principles are completely lost. To make it worse the exercises are usually named for machines instead of principles, whereas the bond of linkage should be strengthened between the result and the principle. If one turns thru a laboratory manual in physics he sees such titles as specific gravity bottle, pulley, wheel and axle, inclined plane, convex lens, Bunsen photometer, etc. etc. One will usually find too that after doing such exercises as the pulley, the inclined plane, the wheel and axle, etc., the students will fail to recognize any connection with the principle of work.

There is seldom a hint to the inexperience teacher on simple and effective means of attaining experimental results. If there is an alternative between a complicated expensive manufactured piece of apparatus and a simple device which could be made in a manual training class or at home, the laboratory manuals almost invariably describe the complicated arrangement. Frequently the principles involved are actually obscured by the elaborateness of the set-up. Seldom is the apparatus stripped to the simplest form which causes the principles to stand out in bold relief.

This supposed dependence of the laboratory course on expensive apparatus has enabled the manufacturers of physical equipment to prey upon boards of education all over the country. The net result is that our physics laboratories are, on the whole poorly equipped. This is the case even where considerable sums have been expended. The equipment of the physics laboratory in the high school need not be very expensive. One does not need a costly hypsometer and double-walled calorimeter set and metal clippings or shot to get reasonably accurate measurements of specific heat. Using short pieces of thick-walled metal pipe capped on one end, such as can be obtained at a plumber's shop, very good results can be obtained by pouring into the cup so formed a known amount of hot water at a known temperature. The only secret of success is the use of a large sample of the metal to be tested. One does not need expensive force boards, inclined planes, model electric motors, photometers, wheatstone's bridges, etc., to do good laboratory work. It is somewhat more convenient to use them if they are available, but in their absence no reasonably skilful teacher need allow the work to be seriously crippled. Profitable courses in radio laboratory work can be carried on with very little more than the parts salvaged from obsolete and defective radio receivers. If encouraged the least bit many boys will be glad of an opportunity to assemble pieces of home-made apparatus either in the laboratory or in a corner of their basement or attic at home. And in such cases it has been my experience that the grasp of principles involved has equalled or exceeded that attained thru the regular laboratory and classroom activities. Indeed the situation affords an opportunity for the use of the best features of the project method, and offers the further advantage that it in no way restricts the field of content materials presented thru the regular school channels.

With our laboratory manuals crowded full of tedious exercises which neither connect with preceding or following work or correlate with the text materials and recitation, with descriptions of elaborate and expensive apparatus with which the laboratory is rarely adequately equipped, with a desultory routine following of instructions in which the student has meagre interest or understanding, is it surprising that the very basis of our laboratory study would be called in question? If you have followed the discussions in professional journals during the last decade, you are aware that between 1920 and 1925 a wave of enthusiasm

for the problem-project method of laboratory conduct swept over the country. It differs from the formal laboratory method in that it aims to arouse self initiated pupil activity in solving some problem which vitally interests the student.

C. R. Mann gives the following characterization in three steps of the term project:

1. A desire to understand the meaning of some fact, phenomenon or experience. This leads to questions and problems.
2. A conviction that it is worth while and possible to obtain an understanding of the thing in question. This causes work with impelling interest.
3. The gathering from books, experience, and experiments of the needed information to answer the question in hand.

George R. Twiss says in his well-known book "Science Teaching:"

"In an ideally arranged course of study the student would go to the laboratory just as a scientist does, . . . to find out at first hand by special appropriate observations and experiments certain essential facts of observation which he needs in the methodical investigation of a scientific problem, and which he cannot so conveniently or effectually find out elsewhere. He differs from the scientist in that he is immature, his knowledge and scientific skill are limited, and he is not trained . . . but being trained."

For several years a controversy raged on the relative merits of the project method and the formal laboratory procedure. The question is not yet settled, tho the agitation has subsided. The project method, bringing into play as it does powerful forces of vitalization and motivation and greater emphasis on pupil initiative and activity, has failed to replace formal laboratory work only because of such limitations as the following:

1. The project method lends itself better to more intensive study of a few problems than to an extensive survey course. It is hopelessly out of the question for a beginner in science to discover for himself any considerable portion of the vast accumulation of scientific knowledge to which the men of genius all down thru the ages have contributed. Specialized study of limited aspects of the subject matter in a beginning course is pedagogically unsound. High school pupils need a perspective view. Their training should cover a wide foundation of explorative and extensive nature. Any attempt later on to broaden out on a narrow foundation must inevitably result in a condition of unstable equilibrium.

2. Typical pupils of our present school population are not scientists in the embryo whose powers of scientific investigation will gradually and certainly unfold under the training of the project method. The large majority of them are not equipped to carry on even the amateur research work which the method involves.

A little later than the project method, there came upon us the storm of the question: demonstration versus individual laboratory method. The skies have hardly yet cleared away, and we hear occasionally the thunder of an article purporting to have clinching evidence one way or another. As has been pointed out in the literature, many of the investigations were made without isolation of the variable factors. Such isolation, difficult as it is when human elements are involved, is a prime requisite for any experimental study. Others studied the learning under different laboratory processes as carefully as the uncertainty and the elusive character of measuring human achievement would permit. A point which has not always been recognized in drawing conclusions, however, is that an apparent superiority of one method over the other does not mean necessarily that one should replace the other in its entirety. I am certain that in our zeal for individual laboratory work following its introduction fifty years ago, we have carried into that phase of the work much material which properly belongs in the lecture-demonstration phase. This being the case we need a wiser distribution of materials between the two phases rather than an abandonment of one in favor of the other. One should remember that historically the lecture-demonstration method is much the older, that it has been tried thoroughly and that fifty years ago it was found very desirable to give considerable emphasis to a supplementary approach thru the individual laboratory method. In my judgment the pendulum has just swung too far, and now we need to take stock again of the materials which lend themselves to more effective study one way or the other and wisely select and distribute the subject matter of both. The project method and the demonstration method both have great merit, but they should supplement and not displace, the individual laboratory study of a central core of experiments which cover an extended range of the subject.

The laboratory has ceased to be a place where pupils verify laws, but it is still a place for students to get concrete sensory experience. The "feel" of the apparatus, its set-up, its adjust-

ment and manipulation, the gathering and recording of experimental data and their association and interrelation with the conclusion, properly drawn, constitute a sensory experience which gives meaning and reality to the principles involved. Particularly in those portions of the work in which the pupil's normal background of experience is meagre, this concrete approach is indispensable.

The most significant statement made by Twiss in his "Science Teaching" is:

> "The teacher should constantly be aware that a general statement means nothing to any one unless it serves to call up in his mind a large number of images and memories of particular concrete facts that are included under it, and that have been repeatedly associated with it and with one another."

A piece of poetry is just a rhyme, a musical composition just a medley of sounds a painting just daubs of color except insofar as their elements have meaning and significance based on the understanding of the observer.

I wish to close with two ideas of pedagogical importance which are of special value in the laboratory. One is that a cardinal principle of teaching demands that each student must enjoy enough of the pleasures of success to stimulate the release of energy for further accomplishment. The amount of effort which a person can exert depends not alone on the size and texture of his muscles, but upon the nervous energy which he puts into a reaction. When a large stone mill burned in Bloomington several years ago it literally rained fire over the south end of town. Everyone was up on his house-top with buckets of water and wet rugs. After the danger was over one of our neighbors called to someone to bring him a ladder to get down. He was asked how he got up, but he didn't know. Marks on the gutter later showed that he had climbed the downspout. The fire released the nervous energy. There is no fire which releases more sustained mental effort than the enthusiasm of success. It may be only trivial success, but it is cumulative. In our laboratories next week let us see to it that every pupil gets some measure of this thrill.

My last sentence relates to the connection between scientific procedure in the laboratory and scientific procedure in the great public questions which confront us. The greatest problems the next generation or two will have to solve are not problems of physics or chemistry, important as these may be. They are our

social and economic problems—the problems of our living together. Can we not do more to fasten in the minds of youth the necessity of approaching problems in any field with the attitude which has characterized our great scientists—the unbiased willingness to get at facts in a case and base a fair conclusion on the evidence presented?

FROM THE SCRAPBOOK OF A TEACHER OF SCIENCE

By Duane Roller

The University of Oklahoma, Norman, Okla.

No man should dream of solving a great problem unless he is so thoroughly saturated with his subject that everything else sinks into comparative insignificance.—*Ernst Mach, in "Popular Scientific Lectures."*

The Russian Soviet Republic considers work the duty of every citizen of he Republic, and proclaims as its motto, "He shall not eat who does not work."—*From "The Constitution of the Russian Soviet Republic," adopted July 10, 1918.*

We must clearly recognize that the sacrifice of pleasure, of whatever sort, or the incurring of pain, is always in itself an evil. Sacrifice is not desirable for its own sake, but only when it is necessary to obtain a greater good; the sacrifice must *benefit* somebody, or else it is a sheer loss and wicked cruelty.—*Durant Drake, Professor of Philosophy at Vassar College, in "The New Morality."*

> What if another sit beneath the shade
> Of the broad elm I planted by the way,—
> What if another heed the beacon light
> I set upon the rock that wrecked my keel,—
> Have I not done my task and served my kind?
>
> —*Oliver Wendell Holmes*

The mediocre man alone gets any happiness out of achievement, for he is ass enough to be able to persuade himself that what he has achieved is signally and finally worth while.—*George Jean Nathan, in "The American Mercury."*

The birth of science was the death of superstition.—*Thomas Henry Huxley.*

Science is busy with the hither-end of things, not the thither-end.—*Charles H. Parkhurst.*

THE SCIENTIFIC STUDY OF SCIENCE INSTRUCTION*

By A. S. Barr
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It is the purpose of this paper to discuss the application of scientific techniques to science instruction. While this is not a new subject, it is sometimes helpful to make a careful re-examination of old subjects. It has many times been said that science has made tremendous progress in the study of the material forces of nature, and that its techniques should be employed in the better understanding of human nature. I believe that the major issues of the twentieth century are social and that their solution may be achieved most directly, immediately, and expeditiously by the methods of science. The problems of science instruction fall within this category.

Before entering upon the discussion of the major theme of this paper I should like to refer briefly to three important phases of this subject which cannot be discussed within the confines of this paper: (1) It is not possible to discuss the many very excellent studies of specific problems of science instruction made both in the classroom and in the laboratory. These are reported in the various journals, yearbooks, and monographs, printing summaries and original reports of such research. (2) It is not possible to discuss the progress made in the development of educational measurements, statistics, and other scientific techniques. As students of education have become better informed about the physical background of measurements, the mathematical background of statistics and the logical background of research techniques, research has improved. Our great problem at present is not the opponents of the scientific study of classroom instruction but proponents who lack the necessary technical background to free their efforts from obvious errors. And (3) it is not possible to discuss the progress and the recent contributions of the formal laboratory type of research as developed in the studies of psychology, sociology, and education. It will be the purpose of this paper to discuss not these more formal applications of research but the informal scientific thinking and

* This paper was read before the Chemistry-Physics section of the Indiana State Teachers Association, October 20, 1932. It appealed to us as an unusually sane blend of common sense and scientific education so we asked for the privilege of bringing it to a larger circle of educators through School Science and Mathematics, Frank B. Wade, Editor for Chemistry.

studies made by the teacher in the classroom. The central theme of this paper is scientific thinking and the classroom teacher.

In the development of this subject I should like to first call attention to the sources of guidance most commonly employed by man in his efforts to understand things, and to discover *truth*. Viewing this matter broadly and historically, man, in general, has appealed to four sources of evidence for his guidance:

1. Man has appealed to *custom and tradition*. Of the totality of man's activities comparatively few are brought consciously to his attention so that he needs to choose among them, to determine their efficacy, or to seek their ultimate logical justification. By far the most of his opinions, attitudes, and actions are determined by the customs of his time or the traditions of his race. This acceptance of custom and tradition is a necessary human economy, but when the fact that a thing is or has always been so is employed as the justification for its continuance, the result, as we all know, may be an appalling stagnation. When man recognized his own mental inadequacies and the temporary character of many of his own adjustments to other men and to nature, a great step was taken in the development of human thinking.

2. Man has appealed to *authority*. In times of storm, pestilence and conflict man often finds the dictates of custom and tradition inadequate. He is driven in these times of felt need from his complacency to newer and better modes of behavior. Savage man with his belief in magic, in charms and the supernatural, appealed in times of crises to the tribal wise men and to his gods. These have been succeeded in civilized nations by secular and religious authority. In early times in nearly all countries the aim, content, and methodology of education, for example, were determined by the authority of the church. In China, the formal education of children began and often ended by a study of the writings of Confucius; in India by a study of the Vedas; in Syria, Egypt, and Arabia by a study of the Koran; in Palestine by a study of the Old Testament; and in Western Europe and America by the study of the Bible.[1] For centuries the church settled not only questions of faith but such secular matters as, marriages and divorce, recreation, and the movement of heavenly bodies. The church gave its sanction to

[1] Trow, William Clark, *Scientific Method in Education* (Boston: Houghton Mifflin Company, 1925), pp. 9–27.

such scientific statements as harmonized with its beliefs and placed all others under ban as heretical.[2] With the growth of the strong secular powers of western Europe the balance, however, passed from church to state, in which one now appeals to kings, parliaments, and legislatures. Not a great many years ago a state legislature in one of these United States enacted, for example, legislation deciding upon the validity of the principle of evolution. From the dawn of civilization man has appealed, and in the absence of more reliable information, rightfully so, to his oracles, to his intellectual superiors, to his church, to his state, to his king, and to his God for guidance.

3. Man has appealed to *syllogistic reasoning* from self-evident propositions based upon experience. The next great intellectual advance of man was made when man began to think about his own thinking. The product of these early intellectual efforts was deductive logic founded by Aristotle and perfected in medieval scholasticism. The scholastic method consisted chiefly in proving and disproving by the use of logical techniques selected statements from Aristotle and the Church Fathers.[3] While the scholastic method purported to furnish good mental training, it tended to degenerate into mere argumentation for its own sake, and as a means of discovering truth contributed relatively little considering the amount of attention devoted to it. Such hair-splitting distinctions as, whether a pig driven to market is held by the man or the rope or whether a shield white on one side and black on the other may be called black or white, defended and opposed by long strings of syllogisms, brought this system of logic into disrepute.[4] The primary weakness of the syllogism, however, was in its premises. These were accepted on the basis of authority or as self-evident from experience. Syllogistic thinking consisted of deducing the consequences of self-evident principles according to the conventions of deductive logic.[5]

4. Man has appealed to *scientific inquiry*. The scientific mode of inquiry with its appeal to facts dates from the opening of the seventeenth century. Galileo made his famous experiment on the rate of falling bodies from the leaning tower of Pisa in 1589;

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[2] Parker, Samuel Chester, *A Textbook in the History of Modern Elementary Education* (Boston: Ginn and Company, 1912), pp. 109–134.

[3] Ashley, Roscoe Lewis, *Early European Civilization* (New York: The Macmillan Company, 1917), pp. 516–519.

[4] Robinson, Daniel S., *The Principles of Reasoning:* An Introduction to Logic and Scientific Method. Second Edition (New York: D. Appleton and Company, 1930), p. 336.

[5] Welton, J., The Logical Bases of Education (London: Macmillan and Company, 1919), pp. 105–106.

he invented the telescope in 1609. Napier published his work on logarithms in 1614; Briggs used decimal notations in 1617; Bacon published his *Novum Organum* in 1620; Kepler offered proof of the Copernicean hypothesis that the earth and other planets move around the sun in 1620; Harvey published his treatise on the circulation of the blood in 1628; and Newton furnished the mathematical proof of the hypothesis of universal gravitation in 1679.[6] From these modest but exceedingly important contributions have arisen the magnificent structure of modern science.

Man's first explanations of the natural phenomena about him were derived from an appeal to the supernatural. This sort of explanation is excellently represented in the savage's belief in magic, charms, witches and other supernatural forces. Being unable to understand the complexity of nature in which he found himself, savage man appealed to the supernatural. These were recorded in the traditions of the tribe and interpreted by the wise men. Gradually, as man emerged from savagery as civilized man, he began to note many real and imagined uniformities in nature, such as, wet feet cause colds; a circle around the moon portends bad weather; one fish dropped into each hill of corn makes better corn; certain farm crops planted in a light moon grow better than when planted in a dark moon; fat men are more jovial than lean; individuals who learn rapidly forget rapidly; and physiognomical features are indicative of intelligence and criminal tendencies. Observations such as the afore named are usually referred to as empirical: thus empirical agriculture, empirical medicine, and empirical education. Much that goes on, today, in the name of education is of this empirical kind,[7] based upon trial-and-error efforts of the profession. Many of the so-called naturalistic laws of science are also empirical, that is, observed uniformities in nature for which no adequate reason or explanation can be assigned.[8] There are many illustrations in the laboratory sciences. I may know, for example, that certain drugs will produce certain effects without knowing the physiological processes involved; or that certain chemicals react in a certain manner without understanding

[6] Parker, Samuel Chester, *A Textbook in the History of Modern Elementary Education* (Boston: Ginn and Company, 1912), pp. 112–119.

[7] Trow, William Clark, *Scientific Method in Education* (Boston: Houghton Mifflin Company, 1925), pp. 19–21.

[8] Welton, J., The Logical Bases of Education (London: Macmillan and Company, Limited, 1919) p. 204.

why they do so, etc. Science is not satisfied, however, with these empirical findings; its ultimate goal is complete explanation. The tremendous significance of the theory of evolution is to be found in the explanatory principle that it offers for so great a range of facts. Newton's law of gravity, the nebular theory in astronomy and the theory of relativity are other examples. We cannot, however, fully explain an observed uniformity in nature until we comprehend its numerous relations, until we discover the deeper nature of the underlying system, and until we understand why it acts as it does.[9] When one is able to so understand the uniformities of nature and when one can offer satisfactory principles of explanation for these uniformities, it is said that one's knowledge is complete, comprehensive, and scientific. Such is the ultimate goal of all science.

There are besides these more formal sources of truth the less formal ones employed in everyday life. While these less formal sources of truth have paralleled, in the intellectual development of man, the more formal ones, with a cerrtain lag, all of them have continued with a curious mixture of truth and fiction into the present. They constitute the intellectual equipment of the ordinary layman of today. One observes in this ordinary thinking the appeal to the supernatural, to authority, to custom and tradition, to syllogism imperfectly executed, and to informal scientific thinking. Of these various sources of evidence, it was not at all uncommon a few years ago, for example, for speakers and writers, speaking and writing on educational topics, to offer their individual experiences, their educational wise men, and educational tradition and custom as evidence for the continuance of various educational practices. Most of the literature of education prior to 1900, valuable as it was, consisted for the most part, with the exception of the great educational philosophers, of just such records of experience.

The aim of the above statement is not to minimize the importance of these several sources of evidence but to call attention to their inadequacies as ultimate sources of truth. I wish, in this connection, to refer briefly to the relation of experience to science and science to philosophy. Science itself, as we all know, is an appeal to experience. James Harvey Robinson[10] has already made a point of the fact that most people do not reason,

[9] Robinson, Daniel S., *The Principles of Reasoning:* An Introduction to Logic and Scientific Method. Second Edition (New York: D. Appleton and Company, 1930), pp. 289–297.

[10] Robinson, James Harvey, *The Mind in the Making:* The Relation of Intelligence to Social Reform (New York: Harper Brothers, 1921).

but rationalize. That is, they employ their own individual experiences and observations to support previously acquired likes and dislikes. While this is true, on the other hand, it is equally true that a keen mind, with some knowledge of the fallacies of common thought, may offer out of the richness of his own individual experiences many shrewd observations of great value. These constitute not only a source of practical guidance but a valuable source of hypotheses for further scientific inquiry. This intimate connection between the modes of thinking employed in everyday life and science is frequently overlooked. In many of its undertakings, science merely begins with the distinctions, tentative generalizations, and the suppositions found in ordinary experience and extends these by making them more definite and consistent. There is already in the language of ordinary life an organization of experience, and it is from this organization of experience that scientific thinking takes its departure. Science, from this point of view, merely consists of correcting, extending, and verifying the familiar.[8]

It has just been said that the fact that an observation is based upon experience is by no means *prima facie* evidence that it is wrong, untrue or erroneous. Very much the same attitude may rightfully be taken toward philosophy. Philosophical thinking has taken on many meanings: (1) It is sometimes taken to mean a form of deductive reasoning superimposed upon the inductively derived principles of science; (2) it is sometimes taken to mean inductive thinking in which the data of science are treated as the materials for super-generalizations at higher levels of integration; (3) It is sometimes taken to mean practical or critical thinking about problems in fields not yet occupied by science; and (4) it is sometimes taken to mean the armchair speculations of dilettantes who have not the facts. It seems to the writer that the objection to philosophy is not to careful thinking of types one, two, and three, but to the speculative day dreaming of type four. There is a large group of silver-tongued, facile-penned, high pressure salesmen with an extraordinary amount of personality that make a living by imposing upon the credulous character of the general populace by means of what we shall call literary misrepresentation. To these, all serious students of education and of the problem of human life rightfully object.

The justification for philosophy is a practical one. The discovery of truth by means of scientific inquiry is a slow and

laborous process. Quite naturally, scientific investigation started with the physical sciences; it was later extended to the biological sciences, and more recently to the human sciences. Philosophy in the hands of the good, keen, critical observer trained in logical habits of thinking and with some sense of evidence has an immediate, necessary, and practical contribution to make to human welfare. Our chief problem is that of preventing unnecessary philosophizing about things that are immediately amenable to scientific inquiry. I think in this year, 1932, that most of the problems of science instruction fall within the province of the methodology of science.

Turning to the more practical aspects of this discussion, I should like now to suggest three applications of the methods of science to classroom instruction:

1. I should like to suggest that its techniques be more generally employed by classroom teachers in the scientific study of the problems of teaching. While there is much excellent laboratory research already completed and in progress the results of laboratory research, as we all know, must not be blindly accepted by the teacher as applicable to the uncontrolled conditions of the classroom.[11] Then too, there are many problems of instruction that do not immediately lend themselves to laboratory research that will have to be worked out in the classroom.[12] Furthermore, from the point of view of the happiness of the teacher and her professional advancement there is nothing more effective for the teacher's self-training than problem solving.[13] The tendency during the last two decades has been away from the memoriter type of education formerly found in so many classrooms and toward reflective thinking and problem solving. Just as this innovation has been looked upon as an improvement in the technique of teaching, its more recent introduction into the self-training of teachers in service has been looked upon as an improvement of the technique for training teachers in service. I am sure that it is not necessary for me to add that the enthusiasm, understanding, and improvement in teaching, resulting from the systematic study of educational problems on the part of classroom teachers, should result in more happiness, understanding, and improvement on the part of pupils.

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[11] Dewey, John, *The Sources of a Science of Education* (New York: Horace Liveright, 1929), pp. 19–21; 28–30.

[12] Buckingham, B. R., "The Public-School Teacher as a Research Worker," *Journal of Educational Research*, XI (April, 1925), pp. 235–243.

[13] Woody, Clifford, "The Values of Educational Research to the Classroom Teacher," *Journal of Educational Research*, XVI (October, 1927), pp. 172–178.

2. I should like to suggest that classroom teachers engage in more of the informal type of experimental thinking in the classroom. When one thinks of experimental thinking, one ordinarily thinks of the laboratory. There is, however, a generalized mode of thinking, the spirit of which a great many people do not seem to catch, which is, after all, the very essence of science itself. In science one measures, throws in an experimental factor, and measures again. The number of opportunities in the classroom for informal thinking of this sort are, of course, endless. One might, for example, observe what happens when the method of instruction is individualized, when the teacher does most of the talking, when visual aids supplant verbal aid, etc. Morrison has suggested this idea in his studies of group attention.[14] Some day when the regular class routine appears to be moving along about as it should be, I would suggest that you make an estimate of the attention, then introduce an experimental factor, such as a series of class reports by a student; thirty minutes of reading from a science text, or anything else that may occur to you and see what happens. The amount of attention will be seen to fluctuate. This fluctuation in attention supplies the teacher, as it were, with a crude measure of her own effectiveness. Much has been said about formal research; the suggestion here offered pertains to informal research. Informal research bears about the same relationship to formal research that informal testing bears to standardized testing. As a mode of thinking, it is, in effectiveness, some place between individual experience at the one extreme and systematic research at the other, on the scale of thinking. It is in many respects the essence of science.

3. I should like to suggest more diagnostic thinking of the scientific sort. In diagnostic thinking one has an observed effect and desires to determine its cause or antecedents. This type of thinking is applicable to most any phenomenon. The nature of diagnostic thinking may be illustrated from a brief analysis of a mechanic repairing a car. The following steps appear to be clearly differentiable:

(a) He first checks the performance of the car.

(b) He looks for the cause or causes of unsatisfactory performance.

(c) From a preliminary survey of the facts at hand and from

[14] Morrison, H. C., *The Practice of Teaching in the Secondary School* (Chicago: The University of Chicago Press, 1926), pp. 103–150.

his past experiences with cars he formulates an hypothesis as to the probable cause or causes of unsatisfactory performance.

(d) He checks the absence or presence of the supposed cause or causes

(e) He makes the necessary repairs, and

(f) He re-checks the performance.

To use this procedure in the classroom, one would first measure the learning, first in a general way and then in a more specific way. Let us suppose that the performance of the whole class or of individuals in the class was found to be unsatisfactory. Having determined the character of the performance, one might then recall to mind, from his own observation, reading, and experience, the probable causes of unsatisfactory work: the lack of intelligence, poor home conditions, poor teaching, etc. One might then formulate some hypothesis or hypotheses about the probable causes of poor work. Having temporarily assumed the probable presence of some conditioning factor, such as the lack of intelligence, effort, or teaching, one might then determine its presence or absence. If this factor were found not to be present another might be projected and so on until a projected factor were found to be present. Having discovered the presence of an assumed cause of poor work one might then initiate some sort of a remedial program. Having applied the program one might again measure the results and so the process might be continued until the performance was improved. The methodology of this sort of thinking is well set forth in both science and logic.[15]

Finally, it should be said that the problems of learning, and teaching are infinitely complex. The scientific method furnishes a mode of bringing these problems of everyday life within the comprehension of man. Without the mechanical controls, simplifying procedures, and objective means of measurement employed in science, man simply gets lost, argues in circles, or otherwise fails to understand the phenomena of which he is part. By introducing the principle of analysis into the understanding of the complex situations of everyday life, by stressing the fallacies of thought arising from unobserved antecedents, by stressing the importance of the control of factors, and by supplanting the subjective evaluations of the ordinary layman by validated

[15] Westaway, F. W., *Scientific Method:* Its Philosophy and its Practice. Second Edition (London: Blackie and Son, Ltd., 1919).

instruments of measurement, man has achieved a better understanding of the material forces about him. The conventional argument is to the effect that the scientific method is applicable to the simple phenomena of the physical world but not to man, mind, and social relationships; the argument is here reversed: the problems of man, mind and social relationships are infinitely complex. They are, in fact, so complex that it is only by the means of science that we may hope to comprehend them.

METRIC SPORTS

By Watson Davis
Managing Editor, Science Service

The adoption of the metric system for the measurement of all track and field events sanctioned by the Amateur Athletic Union is an important step toward a wider adoption of the international system of weights and measures in this country.

For years scientists have used the gram as a unit of weight, the meter as a unit of length, as well as the liter for volume measure and the Centigrade scale for temperature. This allows any scientific measurement to be compared directly with any other throughout the world.

The metric system of measurement in athletics was adopted in "fairness to American athletes." Track and field contestants in America have not had the chance of breaking the important world records because the distances run have been measured in feet and miles, whereas all the rest of the world except Great Britain has used meters. The American records could not be considered in comparison with those of other countries, as the time required, for example, to run the quarter mile (402.34 meters) is not a precise indication of the time required by the contestant to run 400 meters. Heights for pole vaults are of course comparable. The recent Olympic games at Los Angeles run on the international metric system demonstrated the disadvantage of sticking to the British system.

The international metric system has been legal for use in the United States since 1866. There are no barriers to its use in all our activities except those of inertia and the transitory difficulty of changing from one system to another.

One of the youngest of industries, radio, used meters and kilocycles, metric units, from the time of its birth in the scientific laboratory.

Now that school and college athletes will soon be running 100-meter instead of 100-yard dashes and making kilometer runs, students will begin to realize that the metric system is useful outside the physics and chemistry laboratories. That will speed the day when we shall join the majority of the world in using the international system for our everyday affairs.—*Science Service.*

AAA.

Alaska is probably the most promising of all the unexplored places on the globe. With only 59,000 inhabitants it has 590,000 square miles of territory, ten square miles to each inhabitant. The U. S. paid Russia some seven millions for it, and haggled over the price. Alaska's exports in fur, fish, gold and silver amount to over ten million dollars annually. To avoid confusion with Alabama, the postal abbreviation for Alaska is "Aaa."

VERBATIM REPORT OF A RECITATION IN GEOMETRY

By Joseph A. Nyberg
Hyde Park High School, Chicago

This is the second of a series of stenographic reports of what actually took place in a classroom. The first report appeared in the December issue. The following record was taken on Monday of the seventh week of school. There were 39 pupils in the class.

Teacher: Be seated, please. Study the theorem on page 60 for a minute; I'll ask some questions about it later. I'd like to remind the following pupils that their homework last Friday was unsatisfactory. (The teacher read nine names).

P. I handed mine in and you just now handed it back to me.

T. Yes; because it was unsatisfactory.

(2 minutes)

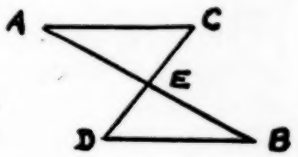
T. Now, how do we prove two lines are parallel? Miss A.

P. Two lines are parallel if the transversal makes two alternate interior angles equal.

T. Exercise 1. What two lines do I want to prove parallel, Miss B?

P. AC and DB.

Ex. 1. $AE = EB$, $DE = EC$.
Prove that AC and DB are parallel.



T. Which two angles must I prove equal, Mr. C?

P. $\angle ADC$ and $\angle DBC$. (The class laughs.)

T. They don't seem to agree with you.

P. Well, then $\angle BDC$ and $\angle BAC$.

T. You said $\angle A$ and $\angle D$?

P. No. I mean $\angle C$ and $\angle D$.

T. That would be satisfactory. In other words, you must have what kind of angles?

P. Alternate interior angles.

T. How can you tell if they are alternate interior angles, Miss D?

P. They are inside of the triangle and that makes them interior; and they are at either end.

T. Those are very poor reasons. Let's hear some other reasons. Why are $\angle C$ and $\angle D$ alternate interior angles, Miss E?

The pupil did not answer.

T. Let's look back a few pages. Page 56. In the figure on that page, angles 1, 2, 7, and 8 are exterior angles; and 4, 5, 6, and 7 are interior angles. By the way, are there any triangles in this figure, Miss D?

P. No.

T. And yet there are interior angles. What must I have in the figure in order to have interior angles when no triangle is present, Miss D?

P. Transversals.

T. Transversals? (With emphasis on the final *s*). How many transversals?

P. Two transversals to one line. (The class laughs.) No. One transversal to two lines.

T. Now in exercise 1, why are *C* and *D* alternate interior angles, Mr. F?

(The pupil did not answer.)

T. Well, tell me the two lines you are thinking of, and name the transversal.

(The pupil still hesitated. The teacher drew freehand on the blackboard a sketch of the figure.)

T. I have mentioned that if you're in doubt about the angles and lines, you should prolong the lines beyond the intersection points.

(In the sketch on the board the teacher prolonged *AC* and *BD*, and also *DC* in both directions.)

T. What are the two lines that have a transversal in my figure, Mr. F?

P. *AC* and *BD*.

T. Correct. *AC* and *BD*. What is the transversal, Mr. F?

(The pupil did not answer.)

T. Well, I'll rub out some of the lines in the figure. (The teacher erased *AB*.)

P. *DC* is the transversal.

T. Now can you tell us why $\angle C$ and $\angle D$ are alternate interior angles?

P. Because they are inside.

T. Inside what?

P. Inside the triangles.

T. That's what Miss D said; and I said she was wrong. There are no triangles in my picture. Why are they interior angles, Miss G?

P. Because they are between the two lines AC and DB.

T. Correct. (Pause.) Miss H, you look as if you were working very hard this morning. I wish you would pay attention to what we are doing. Why are C and D alternate angles, Mr. I?

P. Because they are on opposite sides.

T. On opposite sides of what?

(The pupil mumbled an indistinct answer.)

T. Say it again. You may be right.

P. They are on opposite sides of the transversal DC.

T. Correct.

(There was a momentary pause as if everyone felt relieved to have questions answered correctly at last.)

T. What is it we have been trying to do, Mr. J?

P. Prove AC parallel to DB.

T. Which angles do we use?

P. Either $\angle C$ or $\angle D$.

T. Not *either* angle, but *both* angles. Why are they interior angles, Mr. K?

P. They are on both sides of the transversal. (The class laughs.)

T. Miss L, why are angles C and D alternate interior angles?

P. They're interior because they—they—because they—they are alternate because they are on either side of the transversal; and they're interior because they—because—

T. Mr. M, why are they interior?

P. They are interior because they lie between the two lines; and they're alternate because they are on either side of the transversal.

T. They are not on *either* side of the transversal, but on *different* sides of the transversal.

(12 minutes)

T. Now let's get back to the exercise. How could we prove that $\angle C = \angle D$, Miss N?

P. Because base angles of an isosceles triangle are equal. (The class laughs.)

T. The class is having a good laugh because there isn't any isosceles triangle in the figure. Do the triangles seem to be

isosceles to you? Even if they did *appear* to be isosceles, we would not have any right to say that they are. Let's start again. Miss O, can you prove triangles AEC and BDC are congruent?

(The pupil did not answer.)

T. Mr. P, let's hear you do it.

P. $\angle EAC = \angle EDB$ because—

T. Let's hear the two angles again.

P. $\angle EAC = \angle EDB$ because vertical angles are equal.

T. Why do you think those angles are vertical angles?

P. $\angle D$ and $\angle C$.

T. Mr. C, let's hear you prove triangles DBE and AEC are congruent.

P. $AE = EB$ by hypothesis. $DE = CE$ by hypothesis.

T. And after we get two pairs of lines equal, there is always one other equation we want. What is it, Mr. Q?

P. $\angle AEC = \angle DEB$ and then the triangles are congruent by side angle side equal side angle side.

T. There are just two more steps to this exercise. Let's hear them, Miss R.

P. $\angle BDE = \angle ECA$ because corresponding parts of congruent triangles are equal. $\angle EAC = \angle EBD$ because—

T. Your first statement is correct, but your last statement is unnecessary. What are we trying to prove?

P. $AC = DB$.

T. Read the exercise again. (Pause.) If AC did equal DB, would that help us to prove the lines parallel?

P. We want $\angle 1 = \angle 2$.

T. And why do we want those angles equal? State your answer as a theorem.

P. Those two lines are parallel because the transversal to those lines makes equal alternate interior angles.

T. Miss S, how do we prove lines parallel?

P. By proving some alternate interior angles equal.

T. Yes. And be sure the angles are not vertical angles.

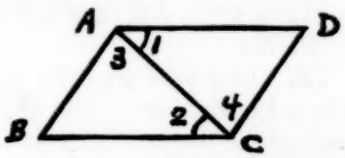
(20 minutes)

T. Let's try exercise 2. Read it carefully, particularly the hypothesis. (Pause.) Which two lines are we to prove parallel, Mr. T?

P. AD and BC.

Ex. 2. $AB = DC$, $\angle 3 = \angle 4$.

Prove that AD and BC are parallel.



T. Before you answer the next question think carefully. Which two angles must you prove equal in order to get AD parallel to BC? Be sure you have the correct angles. Ask yourself: Are they alternate interior angles? Can you tell what the two lines are, and what the transversal is? Can you tell why they are alternate angles? Why are they interior angles? After you have selected the angles, look at the figure again, and see why any other choice of angles would not be correct. I am giving you lots of time because it is easy to get the wrong angles. (There was a slight pause by the teacher after each of these questions, and a half minute pause at the end.) Mr. U.

P. $\angle 1$ and $\angle 2$ are alternate interior angles. They are alternate because they are on different sides of the transversal AC. They are interior because they are between AD and BC.

T. Why not use angles 3 and 4?

P. Well, because $\angle 4$ is bounded by—well, $\angle 4$ is the whole interior angle.

T. Miss V.

P. $\angle 3$ and $\angle 4$ *are* alternate interior angles. The reason you can't use them is because $\angle 4$ is formed by the lines AC and CD. The angles are between the lines but not in the sense they should be.

T. Mr. W.

P. In the hypothesis it gives that $\angle 3 = \angle 4$. And so if these were the angles, you would not need to prove them equal.

T. You mean that the exercise would then be too easy, and hence $\angle 3$ and $\angle 4$ must be the wrong angles. That's a poor reason. Some exercises are as easy as that. Miss X.

P. $\angle 3$ and $\angle 4$ are not formed by the transversal to the lines.

T. But they *are* formed by the transversal AC. Mr. Y.

P. $\angle 3$ and $\angle 4$ are not formed by the lines we are interested in.

T. Correct. What lines are we trying to prove parallel?

P. AD and BC.

T. Correct. Is AD a side of $\angle 3$?

P. No.

T. Is BC a side of either $\angle 3$ or $\angle 4$?

P. No.

T. There you are. The lines that are to be proved parallel must be the sides of the angles. And the transversal must be a side of the two angles. Now how can you prove $\angle 1 = \angle 2$, Mr. Z?

P. By congruent triangles.

T. Prove the triangles congruent, Miss AA.

P. $AB = DC$ by hypothesis. $\angle 3 = \angle 4$ by hypothesis. (Pause.)

T. You have a pair of sides and a pair of angles. What else do you want?

P. A side. $AC = AC$.

T. After the triangles have been proved congruent, what are the two steps that follow, Miss BB?

(The pupil hesitates, and mumbles indistinctly.)

T. I can't hear you.

P. I didn't hear your question.

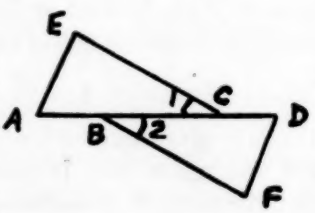
T. After the triangles have been proved congruent, what are the next two steps?

P. $\angle 1 = \angle 2$ because corresponding parts of congruent triangles are equal. AD and BC are parallel because two lines are parallel if alternate interior angles formed by a transversal are equal.

T. Very good.

(26 minutes)

Ex. 4.
$AB = CD$, $EC = BF$,
$\angle 1 = \angle 2$.
Prove: AE and DF are parallel.



Ex. 5.
$AE = DF$, $AB = CD$,
$EC = BF$.
Prove: EC and BF are parallel.

T. Let's try ex. 4. We'll skip ex. 3. What lines are we trying to prove parallel? (A dozen pupils answered AE and DF.) Yes; but we don't recite in chorus. I'll call on somebody. What two angles must we prove equal? Make sure that the sides of the angles are lines that we are interested in. The transversal must be a side of both angles. What are the angles, Mr. CC? (The pupil does not answer.) What two lines are you trying to prove parallel?

P. AE and DF.

T. Do you see any transversal that goes across both of those lines?

P. $\angle 1$ and $\angle 2$.

T. You did not answer my question.

P. The line AD.

T. Now, get this. You are looking for two angles. AD must be a side of both angles. AE must be a side of one angle. DF must be a side of the other angle. What are the angles?

P. $\angle A$ and $\angle D$.

T. $\angle A$ and $\angle D$ are the correct angles. (The teacher drew quickly a sketch showing the lines AE, AD, and DF, explaining and pointing, "Here's one angle. Here's the other angle. The lines that we are to prove parallel—this line and this line—are sides of the angles.")

T. How will you prove $\angle A = \angle D$, Miss DD?

P. By proving the triangles congruent.

T. Yes. Let's see how easy it is. The hypothesis says $EC = BF$ and $\angle 1 = \angle 2$. Next it says that $AB = CD$. But AB and CD are not sides of the triangles. Mr. EE.

P. You can get it by subtraction.

T. Or by addition.

(32 minutes)

T. For to-morrow's homework write out both ex. 4 and ex. 5. Let us see how we construct the figure for ex. 5. The hypothesis says that $AE = DF$, $AB = CD$, and $EC = BF$. First I draw any line and mark on it two points, A and D. Draw any triangle that resembles AEC. (The teacher does this at the board.) How shall I locate the point B? Can I choose it any place on the line AD, Miss FF?

P. Make $AB = CD$.

T. Next I must locate F according to what the hypothesis says about F. How is F fixed, Mr. GG?

P. Measure AE and use AE as a radius and D as a center, and draw an arc below AD. Then using EC as a radius and B as a center, draw another arc intersecting the other one. The intersection point if F.

A pupil disagreed, saying "He didn't copy the right angles."

T. Does ex. 5 say anything about angles in the hypothesis? Let's look at ex. 4. The figure for ex. 4 looks like the figure for ex. 5 but it's constructed differently. In ex. 4 we make $AB = CD$. What should we do next, Miss HH? (The pupil did not answer.) Miss II?

P. Draw any angle at C, and copy it at D. Then make $EC = BF$.

(40 minutes)

This recitation took place on a Monday. The work of the previous Friday had consisted in proving the theorem about lines being parallel if two alternate interior angles were equal. The teacher stated that the assignment for Monday consisted in some review exercises (which were therefore not discussed during the recitation) because Friday's work had not advanced to the point where the pupils were ready to use the theorem that has been proved. Hence the objective in Monday's work was to learn how to apply the theorem.

The class in pedagogy may discuss the following points:

1. How can a class be taught to select correctly the angles that must be proved equal to get certain lines parallel?

2. If several pupils cannot select the angles correctly, how should the trouble be remedied? Can the teacher expect that this trouble will gradually be overcome as the recitations proceed, or should the day's work be set aside and the subject of angles related to two lines and a transversal be retaught at once?

3. Should a recitation on Monday differ from one on any other day?

4. Would there have been fewer incorrect answers if the figures had been constructed on the blackboard instead of having the pupils look solely at the figures in their textbook?

5. Is there anything to be gained by requiring the pupils to use the figure in a book rather than on a blackboard? Are blackboards used after a pupil leaves school?

6. Which is the more difficult task (a) selecting the correct alternate interior angles, or (b) defining alternate interior angles? What should be done with a pupil who can select the angles correctly but cannot define the words? Before consulting a textbook write a definition of alternate interior angles, and then compare your definition with the explanation in a textbook.

Promote then, as an object of primary importance, institutions for the general diffusion of knowledge. In proportion as the structure of a government gives force to public opinion, it is essential that public opinion should be enlightened.—GEORGE WASHINGTON.

A COMMON SENSE BASIS OF CHEMISTRY TEACHING IN SECONDARY SCHOOLS

Part III. Lecture-Demonstrations

By G. T. Franklin

Lane Technical High School, Chicago

In a previous article some suggestions were made for the improvement of individual laboratory work. It was also suggested that when lecture-demonstrations are closely correlated with individual laboratory work, they may be made of great value. There are many experiments, which, for various reasons such as danger of explosions or danger from poisoning, or by the nature of the equipment required, are unsuited to individual laboratory work. However, many teachers feel an imperative need of using the experimental work as a basis for the discussion of fundamentals. Experiments recommended for this part of the course include:

(1) The preparation and the study of the properties of chlorine, carbon monoxide, arsine, and even hydrogen sulfide;

(2) Certain experiments of an explosive nature such as the combustion of calcium in oxygen, the reaction of sodium and potassium with water and acids in general,

(3) Elementary oxidation-reduction reactions, and

(4) Conductivity experiments.

POISON GASES

Where the laboratory is not well supplied with hoods, or where the single hood generally found in chemical laboratories is inadequate, the preparation and properties of chlorine may be studied with profit by the demonstration method. This can be accomplished by the teacher without the use of a hood with no discomfort to the class. This work should be followed by a laboratory exercise in which the pupil investigates various ways of preparing chlorine, using only sufficient materials to make detectable amounts of the gas (1). Incidentally the pupil reviews the lecture experiment and the properties of the gas are noted by first-hand experience.

Most teachers are not willing to permit large classes to generate carbon monoxide. The lack of odor of the gas gives no warning of its presence. The usual methods of preparation with oxalic or formic acids are readily carried out by the instructor with safety, even though no hood is used. The need for a study

of this gas, one of the important constituents of many gaseous fuels and the most used reducing agent in metallurgical processes, is great. The difference between the explosion obtained by kindling mixtures of carbon monoxide and air is compared with mixtures of hydrogen and air, also acetylene and air, is readily demonstrated and carries with it value. Many ways of demonstrating properties of the gas occur to teachers.

In many cases it is probably best for the teacher to demonstrate the preparation and properties of hydrogen sulfide, preparing at the same time a supply of hydrogen sulfide water for the pupil's laboratory problem in the study of the formation of metal sulfide precipitates and other studies common to the problem (2). The tarnishing of silver coins is suggested and the subsequent cleaning by the use of cyanide solutions or salt solution and zinc or aluminum foil (3).

The preparation of arsine and the study of its properties is always interesting and appropriate for lecture demonstration work. The combustion of arsine in abundant air and in limited air afford a comparison with previous studies in which the combustion of hydrocarbons may produce soot or carbon dioxide and the combustion of hydrogen sulfide may produce sulfur or sulfur dioxide depending upon the concentration of the air present. If a fairly rich mixture of hydrogen and arsine are burned a white smoke showing arsenic trioxide is noted. The well known Marsh test for arsenic is shown by holding a cold vessel in the flame or by heating a hard glass tube through which the arsine is passing.

EXPERIMENTS INVOLVING SOME DANGER

There is always some hesitation on the part of careful teachers in providing classes with sodium and potassium to use with water or acids to prepare hydrogen. However, there is a feeling that the experimental work is needed. If a test tube containing hydrochloric acid is used and a comparatively small piece of sodium or potassium is used, the dangers from explosion are not bad. If the reaction once creates an atmosphere of hydrogen in the tube the chances for explosion are greatly lessened. The combustion of sodium, potassium, and calcium in oxygen may be demonstrated to advantage by the teacher. In this case the danger arising from the combustion of sodium or potassium is not to be dreaded. The problem of heating the metals to their kindling temperature before inserting into a bottle of oxygen is

rather difficult for the beginner. In the case of calcium, a very hot flame is needed to indicate a slight combustion in air. The insertion of the burning calcium into a bottle of oxygen is followed by a brilliant flame and much heat. The bottle is easily broken by the high temperature created. This work should not be a substitute for the pupil's experiments of a like nature, but should enrich the experience by frequent repetition of the same idea with different materials. The principles involved are more likely to be remembered by a combination of the methods.

OXIDATION-REDUCTION REACTIONS

The introduction of theoretical treatments of the subject of valence into elementary courses in chemistry creates a need for experimental work illustrative of the theories. There is no apparatus so necessary for the purpose as an oxidation-reduction cell and a good lecture table galvanometer. The electrodes may be simply made by fusing a copper wire at one end and inserting a short piece of platinum wire into the fused copper. The sealing of this copper-platinum wire into a glass tube is a simple matter (4). Small beakers are convenient to use for the half-cells. The connections and the general hook up of the apparatus (5) are so well known that they need no further mention. When a study of replacement reactions is being made suitable demonstrations may be done by using in one of the half-cells a platinum wire and hydrochloric acid and in the other half-cell a salt solution and various metals. The deflection of the galvanometer needle gives some idea of the activity of the metals. The source of the current and the direction of its flow are readily worked out. The relation between the formation of hydrogen on the platinum electrode and the formation of hydrogen in electrolysis experiments may be pointed out. In one case the mechanical action of the dynamo builds up excess electrons on the cathode, while in the oxidation-reduction cell the tendency of metal atoms to lose electrons and become ions causes the same effect. Thus it may be pointed out how magnesium, zinc atoms, etc., lose electrons readily, while copper, silver, and other metals do not furnish electrons to discharge hydrogen ions.

The use of potassium iodide-starch solution is always interesting and instructive. The starch solution may be conveniently made by stirring powdered starch into water and then heating it boiling hot. If the mixture is allowed to stand, a clear solution

may be decanted. A little potassium iodide is dissolved in the starch solution, avoiding excess of the potassium iodide. If too much iodine is set free in a starch solution, the test may have a green tinge in it due to a combination of blue with the brown color of the iodine. This is not desirable. The solution thus prepared may be kept indefinitely. If this solution is used in one cell with a platinum electrode and in the other cell a platinum electrode and an oxidizing agent such as ferric chloride, chlorine water, bromine, etc., the platinum wire in the starch solution rapidly becomes coated with blue which soon spreads throughout the solution.

Another solution of equal interest is a mixture of potassium sulfocyanate and ferrous salt solutions. If this solution is used in one cell with platinum electrode and an oxidizing agent in the other, the wire in the ferrous salt solution rapidly turns red and the red color eventually spreads throughout the solution. All such experiments when observation is made of the deflection of the galvanometer needle and equations are written for the reaction that takes place in each half-cell afford a means of teaching modern chemistry with a proper basis. They may be made the means of eliminating from the literature false ideas obtained without the use of such experimental facts.

CONDUCTIVITY EXPERIMENTS

Conductivity apparatus is indispensable to the teacher of beginning chemistry. Its preparation may be made as simple as that of the oxidation-reduction apparatus (6). Platinum wires for electrodes, a small lamp board for resistance, an electric light connection are all that is needed. With this apparatus the teacher shows the difference between strong acids and weak acids, strong bases and weak bases by the difference in the glow of a small lamp in series with the cell. By demonstrating that ammonium hydroxide is a weak base and carbonic acid is a weak acid and then showing the good conductivity of ammonium carbonate solution, the foundation is laid for the statement that salt solutions are strong electrolytes regardless as to whether they are formed from strong or weak acids and bases. With the cell it may be demonstrated that if a solution of an alkaline earth base is used with carbonic or sulfuric acids the ions are removed sufficiently to cause a small lamp to go out (7). By continuing the addition of carbonic acid to a calcium or barium hydroxide solution the formation of an acid salt more soluble

than the normal salt is noted with the consequent reformation of ions and the small lamp lights up again. The use of this cell in the hands of the skilled teacher may be made to do much. The excuse for the teacher-demonstrations is that usually equipment and supplies for individual laboratory work of this kind are inadequate. A part of the work is supplementary to individual laboratory work in which a study is made of double replacement reactions that go to an end through the removal of ions from solution.

RÉSUMÉ

In the series of papers on "Common Sense Basis of Chemistry Teaching," it has been pointed out that

(1) The teaching of chemistry without individual laboratory work is not real chemistry instruction and has doubtful cultural values,

(2) The individual laboratory method answers criticisms of methods in general educational practice very well and thus to abandon the idea is unthinkable; to improve the method is the worthy aim,

(3) Lecture-demonstration work has an important rôle to perform in continuing for the mass interesting demonstrations, correlating the work with the experience of the individual worker,

(4) The lecture demonstration-method should not be a substitute method but an addition method entering into the domain of scientific study where, on account of the dangers involved or the difficulties of the technique of the apparatus used, or the great cost of materials needed for individual laboratory work, the teacher plays his part—inspirational as well as instructional,

(5) Individual laboratory work is best adapted to the needs of pupils from a common sense basis. The evaluation of objectives and the use of examinations of the traditional type to determine relative values of procedures are not easily carried out—it is not a problem for the application of strictly scientific methods.

SUGGESTED READINGS

1. The Chicago Chemistry Teachers, *Chemistry Manual—Beginning Semester*, p. 55, Lyons and Garnahan, Chicago, 1931.

2. *Ibid.*, *Advanced Semester*, p. 69.

3. Arthur Haut, "Oxidation-Reduction Demonstrations," SCHOOL SCIENCE AND MATHEMATICS," *30*, pp. 361–365, April, 1930.

4. *Ibid.*, *31*, p. 828, October, 1931.
5. *Ibid.*, *30*, p. 361, April, 1930.
6. G. T. Franklin, "Some Uses of A Conductivity Cell," *ibid.*, *30*, pp. 907–909, November, 1930.
7. *Ibid.*

MAGNETS: AN INTERMEDIATE-GRADE UNIT IN SCIENCE

By Bertha M. Parker
Elementary School, University of Chicago

A unit about magnets has long formed a part of the fourth-grade course in science in the University Elementary School of the University of Chicago. The unit has proved to be very satisfactory. It leads to certain definite understandings of our environment—understandings well within the reach of children of the intermediate-grade level; it affords much opportunity for individual experimentation, for the manipulation of apparatus, and for the construction of simple toys illustrating scientific principles; and it provides opportunity for independent study. Moreover, it serves as a foundation for the later study of electric circuits and of ways of sending messages by means of electricity. A detailed discussion of the unit is presented here with the hope that it may prove helpful to those teachers who are engaged in working out programs in science for the elementary schools.

The unit is organized about the following cores of thought:

(1) There are two kinds of magnets: permanent magnets and electromagnets.

(2) All magnets attract iron and steel.

(3) Magnets have poles. Opposite poles attract each other; similar poles repel each other.

(4) The earth acts as a huge magnet with magnetic poles.

(5) Electromagnets are much more important than are permanent magnets—they can be made much stronger than permanent magnets, and they can be made to lose their magnetism instantly.

The equipment used in the unit is not elaborate. It includes permanent magnets of various shapes and sizes, home-made electromagnets, dry cells, switches, iron filings, toy electric motors, magnetic compasses, electric buzzers, an electric door bell, a telephone receiver, a home-made electric questioner, a telegraph set, and a toy derrick. In addition, materials for the

making of magnetic boats, electromagnets, and compasses are provided.

Of course, the procedure in any given unit varies somewhat from time to time. The plan here outlined should not be thought of as a plan from which no departures are permitted. However, although there are variations in detail, the general plan of procedure remains the same.

The initial stage in procedure is a period of direct teaching. To introduce the unit, the teacher shows a permanent bar magnet to the class, and the children are asked to tell what it is. When they suggest that it may be a magnet, someone is asked to find out whether or not it is. The person chosen shows that it is a magnet by picking up paper clips or small bits of iron with it. The members of the group are then led to discuss previous experiences they have had with magnets. As a rule, many of them own small horseshoe magnets, many of them have played with magnetic jackstraws and magnetic fishponds, some of them own compasses, and a few of them have seen big electromagnets at work. Permanent magnets of several sizes and shapes are next shown to the class. The children find out, by counting the number of paper clips or nails which each magnet will pick up, that magnets vary in strength.

A very simple experiment serves to raise the problem: What materials do permanent magnets attract? In this experiment two pins are used—a steel pin and a brass one. They look alike, since the brass pin is coated with tin. The teacher puts the steel pin on the demonstration table and asks some member of the group to pick up the pin with a magnet. After the child has done so, the teacher removes the steel pin from the magnet and, without making the substitution obvious, places the brass pin on the table. Another member of the group is asked to pick up the pin with the magnet. He is, of course, much puzzled when he finds that he cannot do so. When the children discover that two pins are being used, they try to explain why the magnet will pick up one pin and not the other. The following two explanations are commonly advanced: (1) One pin is heavier than the other, and (2) the two pins are made of different materials although they look alike. By experiment, the second explanation is found to be the correct one. Each member of the group is then given a bar magnet and is told to find out, by testing as many materials as he can find in the science room, what materials a magnet will attract. The findings are then discussed.

The children come to the conclusion from their experiments that magnets attract only iron and steel. Since obviously they have not been able to test all materials, they are asked to check their conclusions by reading. They learn, from reading a paragraph in the *Book of Electricity*,* the science reader used in this unit, that magnets attract cobalt, nickel, and certain other substances slightly.

Experiments which show that magnets will act through materials which they do not attract and that they can even be made to pick up pieces of materials which they do not attract are performed. The poles of a magnet are pointed out, and the children find that opposite poles attract each other while similar poles repel each other.

Each member of the group then makes a permanent magnet of a steel pen. He magnetizes the pen by rubbing it with one pole of a permanent magnet. After he has followed directions for magnetizing the pen, he tests it in the following manner: He pushes the point of the pen into a flat cork in such a way that the pen stands upright. He places the cork in a pan full of water and holds first one pole, then the other, of a bar magnet near the top of the pen. If one pole of the bar magnet chases the cork and pen away, the pen is considered well magnetized.

Pocket compasses are examined, and the use of magnets in compasses is discussed as the most important use of the permanent magnet. The location of each magnetic pole of the earth is pointed out on a globe, and the reason for the fact that compass needles, as a rule, do not point exactly north is explained. A picture of the aurora borealis, or northern lights, is shown, and the children are told that the earth's magnetism is believed to have something to do with this phenomenon.

An electromagnet is next shown to the class, and the children find by experiment that the magnet will attract nothing unless a current of electricity is flowing through it. The magnet is attached to a movable toy derrick, and is used to move iron filings from one place to another. Pictures of huge lifting magnets are examined. As a rule, the members of the group suggest experiments to be performed with the electromagnet by asking such questions as, "Is that electromagnet stronger than our big U-shaped magnet?" and "Will an electromagnet act through glass just as a permanent magnet will?" Experiments enable

* Bertha M. Parker, *The Book of Electricity*. Boston, Houghton Mifflin Co., 1928. Pp. xii+314.

the children to answer the questions they have raised. To emphasize the importance of the electromagnet, the teacher shows a telegraph sounder, a telegraph relay, an electric doorbell, a buzzer, an electric motor, a telephone receiver, and a small generator to the class, and the children are asked to find the magnet or magnets in each piece of apparatus. The buzzer, the bell, the sounder, the relay, and the telephone receiver are in turn connected with a dry cell, and the children watch the movement of the iron armature or diaphragm as the circuit is made and broken. The motor is used to run a toy saw, and the generator is made to furnish current for a small electric lamp.

As the next step, the class looks over the directions for experiments given in Chapter XIV of the *Book of Electricity*. All of the experiments which have not already been performed are performed, and the conclusions are checked by reading.

Each member of the group is then given the materials needed for the making of an electromagnet—an iron machine bolt about two and one half inches long, and about six yards of No. 24 double-cotton-covered copper magnet wire. As soon as a child has finished winding his electromagnet, he connects it with a switch and a dry cell and tests it. When he has succeeded in connecting it so that it works satisfactorily, he draws a diagram showing how he made the connections. The diagram serves as "payment" for the materials used. No member of the group may take his magnet home until he has "paid" for it.

From time to time during the period of direct teaching various games are played. A "password" game helps acquaint the children with the new vocabulary of the unit. At the end of a day's lesson, the children of a group select, to serve as a password, a word which they consider important in the study of the unit. The word, for example, may be "repel." When the group comes to the science room the following day, no member is allowed to enter the room unless he can whisper the password as he enters. Any member who does not know it is given a slip of paper on which the word is written, and he must write the word ten times before he is permitted to enter. Another game is played with a home-made electric questioner. The class is divided into two groups. A chart on which there are questions about magnets is placed on the questioner. A child from one group is told to find the answer to a certain question on the chart. He has only one chance. If the bell of the questioner rings when he holds the wire on the binding post above the answer he believes to be the

correct one, his answer is right, and his side scores one point. The sides take turns until all the questions have been answered. A third game is called the "game of poles." One child in the group arranges on the demonstration table two or three magnets in any design he pleases. He covers the magnets with a piece of cardboard. Iron filings are sprinkled on the cardboard. The teacher then points out two poles which are close together and asks each child in the group except the child who arranged the magnets to tell from the arrangement of the filings whether the poles are opposite or similar. The cardboard is removed, the children check their answers, and each one who answered correctly scores one point for himself. Another child then arranges the magnets, and the game continues.

The second stage in procedure in each unit is a period of independent study. As soon as a child has finished his electromagnet and has "paid" for it with a diagram, he is given a "work sheet"—a mimeographed page of exercises. He works independently and at his own rate of speed through these exercises. The exercises are based upon the chapters about magnets in the *Book of Electricity*. The exercises are simple, as the following examples show:

(1) Tell two ways in which permanent magnets differ from electromagnets.

(2) Make a list of ten ways in which electromagnets are used.

(3) What helped make it possible for sailors to go on long voyages of discovery in the thirteenth century and later?

(4) Copy figures 43C and 43D, page 96. Mark the poles in these diagrams.

All of the work outlined by the work sheets is done in the science periods. The work sheets are not taken away from the science room. As soon as a child completes an exercise, he presents it to the teacher. If it is satisfactory from the standpoints of both science and the mechanics of written expression, the teacher accepts the exercise, and the child starts on the next one.

Each member of the group is given a true-false test as soon as he has completed the required exercises. If he makes mistakes, he is sent to repeat experiments or to reread certain paragraphs, and he is then given the test again.

If a child finishes the test in advance of other members of the group, he is given a mimeographed page of "optional" exercises. The optional exercises are of such a nature that, to most chil-

dren, they serve as an incentive to work without waste of time. Among them are the following:

(1) Make a magnetic boat according to the directions given on pages 119–122 in the *Book of Electricity*.

(2) Use an electromagnet to separate pieces of iron and steel from scraps of other metals.

(3) Connect a motor, a switch, and a cell.

These exercises are truly optional. A child may choose from the exercises suggested any which appeal to him. He may, instead, read any of the science books or magazines in the science room. He may suggest and attempt exercises other than those outlined on the mimeographed page. During the optional exercise period, the only requirement is that the child carry on some worth while science activity without disturbing the other children in the group.

The final stage in procedure in this unit often takes the form of a series of demonstrations for a visiting class. A fourth-grade group, for example, may ask a lower-grade group to visit the science room during the fourth-grade group's regular science period. Each member of the fourth-grade group shows to the visitors some piece of apparatus or some experiment and explains it.

While the unit on magnets is now a part of the fourth-grade course in the University Elementary School, it has been used with success with both fifth-grade and sixth-grade classes. A fourth-grade class can cover the unit as it is here outlined in in from ten to twelve hours of class time. A fifth- or sixth-grade class can, as a rule, cover it in less time.

A science group in the University Elementary School is usually made up of about twenty children. If the unit here discussed is taught to a large group, certain modifications in the procedure must clearly be made. Those modifications do not lessen the value of the unit greatly. Even with a large group, the author believes, the unit can be so handled that it will make a distinct contribution toward the realization of the large objectives of science in the elementary school.

Above all things, I hope the education of the common people will be attended to; convinced that on this good sense we may rely with the most security for the preservation of a due degree of liberty.—THOMAS JEFFERSON.

AN ADVENTURE IN EXTRA-CLASSROOM TEACHING*

By Ray C. Soliday

Oak Park and River Forest Twp. High School
Oak Park, Illinois

It seems probable that every teacher in the classroom and every administrator in the office frequently feels the need for more intimate contacts with the students. This need is two-fold: to foster a better spirit of cooperation, and to give the student a more complete understanding of the values which the school should have for him. Opposing this need just described is the feeling that the teacher must remain aloof from his pupils and maintain a superior and ultra-dignified attitude in order to preserve the effectiveness of his teaching.

This paper is presented in the belief that it illustrates a method by which worthy service may be rendered to pupils of several types. Further, it is proposed that the teacher benefits in no small degree by the close contacts with the students under more natural conditions than exist in the classroom. It is hoped that the experience described may encourage other teachers to attempt similar projects. It is especially suggested that those interested consider the Chicago Pageant of Progress as a goal for educational trips in 1933.

When articles concerning the recent eclipse of the sun began to appear in scientific periodicals and newspapers, they were of course used in General Science classes to promote interest in the astronomical unit. A few of the students soon raised questions concerning the possibility of organizing a group to see the eclipse in the path of totality. The whole class became enthusiastic. Subsequent discussions considered the factors of distance, costs, time required, suitable projects for eclipse study, values of such an undertaking, and the work of professional astronomers. Through this thought of the eclipse, we were able to maintain an unusually high degree of interest in all the regular topics of this unit of science. In addition, we gave some attention to the spectroscope and to solar photography. We had in the class an unusually serious-minded boy who had already planned to

* This article reviews a trip to Maine recently completed by three of the high school students and the writer, for the purpose of photographing and studying the total eclipse of the sun. The plans for and organization of the expedition are explained; the equipment used at the eclipse is described; values and costs of such travel are summarized; and suggestions are made to teachers considering similar vacation activities.

make astronomy his life-work, and it was he who became the leader in planning the trip to Maine.

By the first of June it was definitely decided that a small group of us would attempt to witness and photograph the sun, while eclipsed. It was understood from the start that it would be a purely private affair, with no recognition from the school. Since the matter of expense was paramount it was decided to make a camping trip to materially reduce costs. Boys at once began seeking methods of earning and saving a few dollars. That the trip might be wholly a pupil project, the problems of selecting and constructing the observing equipment were left entirely in the hands of the boys making up the party. The boys were greatly assisted by the kind interest and advice of Dr. Frost of Yerkes Observatory and Dr. Lee of Northwestern University. These men emphasized the desirability of limiting our efforts at the eclipse to a very few fields of observation. The following description of the equipment used is in the words of Edwin P. Martz, Jr., the young amateur astronomer now a junior in the high school:

"A spectrograph of three feet focal length, a coronal camera of the same e.f.l., a two and one half foot camera, and a two inch telescope were the instruments taken along for recording the eclipse. These were, with the exception of the lenses, almost entirely of home construction. Spectacle lenses were used for the cameras and telescope. A small diffraction grating replica of about 25 mm. $\times$ 30 mm. aperture obtained from a school spectroscope was used objectively in the spectrograph. The mountings were simple wooden affairs requiring no apparatus other than common woodworking tools to construct. The lenses were short of two inches in diameter and of 36 to 70 inches e.f.l., of from one to two diopters, obtained from an optician at about $1.00 each. The grating replica of 14,500 lines per inch lists at $4.50.

"A slit made of two razor blades was utilized for obtaining coronal spectrograms in conjunction with the spectrograph, though the flash spectrum and chromospheric spectrums were photographed without it. A small object glass from an old folding telescope was used as the collimating lens for the slit, and a pair of field glasses was rigged up with a diagonal mirror as a finder. Verichrome and Plenachrome film packs were used as being most adaptable to our purpose.

"The cost of wood, paint, bolts and other miscellaneous ma-

terial was negligible, and the entire outlay inclusive of lenses, films, test photos, etc., was not more than ten dollars.

"However, regardless of the money put into the instruments, regardless of the results obtained, and of the scientific value or lack of value of these results, the construction and operation involved were in themselves well worth the time and labor expended. Practical experience in woodworking was obtained along with a wealth of experience in the application of optics and constructional principles of the scientific instruments mentioned."

At Freyburg, Maine, we were kindly permitted to camp on the grounds of the Indian Acres Camp for boys, near the Northwestern University field station. Perhaps the most inspiring features of our trip were the camps of the various astronomical expeditions, such as the Lick Observatory, University of Michigan, Georgetown University and Northwestern. The equipment and the exactness of procedure in these camps will ever remain as ideals for these younger students who visited these camps before the eclipse.

Concerning the eclipse itself and our attempts to photograph it, little need be said. We were very fortunate in having good visibility during the period of totality. Although our mistakes in equipment became only too obvious, we were successful enough to feel well repaid for our efforts.

Although the eclipse was our main goal and chief interest, the writer wishes to emphasize his enthusiasm for travel in general as a teaching method. Travel, intelligently directed and guided, is the great educator, and should be utilized by our educational agencies including the schools. Millions of tourists and other travellers may drive hundreds of miles daily without seeing anything of interest, but we found the miles between Chicago and Maine teeming with features fascinating and stimulating. The contrast between this type of education and that in the school is startling indeed. In school we have our education done up in very distinctly labeled packages, this one history, that one science, and another economics. Not so on the highways across the states.

Geology proved an interesting subject when stimulated by the various spurs of the Appalachians, the rock called Manhattan, the Palisades, the lakes of New England and the Finger Lake region, Niagara Falls and the sand dunes of Canada and

Indiana. The coal-producing regions of Pennsylvania suggested the problems of fuels and their distribution. The oil refineries of Bayonne, N. J., and Whiting, Indiana, added fuel to this topic.

The new George Washington Bridge, Brooklyn bridge, Bear Mountain bridge, the Holland tunnels and the new elevated superhighways turned our conversations to engineering. The economical aspects of such tremendous expenditures for transportation raised many questions for the future to answer. The subways of New York versus the lack of subways in Chicago again turned our thoughts to geology, engineering and the dependence of city planning upon the circumstances often beyond the control of mere man.

The land through which we travelled was filled with historical interest. As we crossed the Ohio river we noticed those typical river boats steaming against the current. How tremendous a part they had played in the development of the great middle west! What role remains for them in the future? We passed within a few miles of Gettysburg. We stopped for food in a small town named Fredericksburg. Was it *the* Fredericksburg, or just another one? Where was Harper's Ferry? How far north did the Southerners get? Dozens of such questions came to the lips of these eager and interested boys as we drove on and on. And surely the relations and interconnection of so many questions and topics gave a clearer conception of the values and meanings of our previous studies in school. Would not a few days spent in this manner give form and meaning and interest and value to the classwork of the preceding months? Surely so.

I am convinced that two weeks' time could scarcely be spent in a more economical or more profitable vacation. Total expense for two weeks' time and 2500 miles' travel was $15.00 per person. Even in times such as these there are boys in nearly every school who could afford such a trip. And I heartily insist that such trips under the guidance of an interested teacher are of tremendous value and inspiration to the high school student. Although there are teachers who cannot spend even two weeks in such a manner, there are surely thousands of others who would get great enjoyment and profit from such an experience. If our schools could incorporate educational travel into their programs, as do schools in some other countries, the benefits might well repay such an endeavor.

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON
State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS OF PROBLEMS

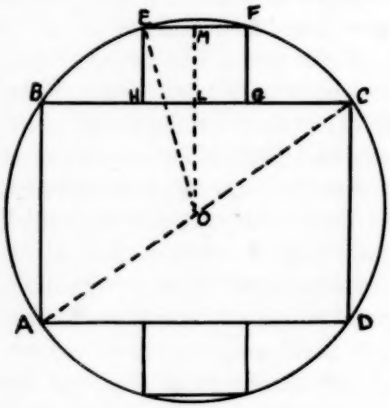
Note.—Persons sending in solutions should read carefully the instructions about the form of the solutions and the ink-drawn figures. Many times, a good solution is received, but poorly arranged and no India-ink figure given. Contributors are requested to give their full addresss. This is for the convenience of friends of this department who write for this information.—Editor.

1240. *Proposed by Ralph Newman, Clarksville, Arkansas.*

A cube whose diagonal is $2a$ is placed in a sphere whose radius is a. What is the length of an edge of the largest cube which can be placed in one of six equal spaces between the cube and sphere?

Solved by Louis Scinta, Mathematics Club, Hutchinson Central High School, Buffalo, New York.

The figure represents a diagonal cross-section of the cube inscribed in sphere O. Obviously, the figure also must contain the diagonal cross-sections of two small cubes, whose sides are to be found:



Construction
Draw $OM \perp EF$
A = radius of sphere (given)
Let $X = EH$, unknown side.
Solution:

$$\overline{AB}=\frac{\overline{AC}}{\sqrt{3}}=\frac{2a\sqrt{3}}{3},\quad \overline{EF}=\overline{EH}\sqrt{2}=X\sqrt{2},\ \overline{EM}=\frac{\overline{EF}}{2}=\frac{X\sqrt{2}}{2}$$

$$\overline{MO}^2=\overline{EO}^2-\overline{EM}^2 \text{ or}$$

$$(\overline{ML}+\overline{LO})^2=a^2-\frac{X^2}{2},\ \text{but } \overline{ML}=X$$

$$\overline{LO}=\frac{\overline{AB}}{2}=\frac{a\sqrt{3}}{3}.$$

$$\left(X+\frac{a\sqrt{3}}{3}\right)^2=a^2-\frac{X^2}{2} \text{ which gives us}$$

$9X^2+4a\sqrt{3}X-4a^2=0$ which in turn gives us

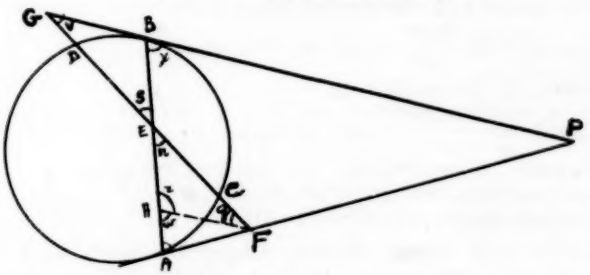
$$X=\frac{2a\sqrt{3}}{9}.$$

Also solved by W. E. Bucker, Wellsdale, Pa., D. Moodey Bailey, Athens, W. Va., Armand H. Lundquist, Idaho, Delbert Eggenberger, Normal, Ill., A. Mac Neish, Chicago, and C. W. Trigg, Los Angeles, Calif.

1241. *Proposed by H. D. Grossman, New York City.*

Given a circle with chord AB, tangents AP and BP, and Chord CD cutting AB in E, AP in F, PB in G. Prove $CE=DE$ if $CF=DG$.

Solved by A. Mac Neish, Chicago.



1. $AP=PB$ and therefore $\angle A=\angle X$
2. $\overline{BG}^2=GD\cdot GC=GD(GD+DC)$
3. $\overline{AF}^2=FC\cdot FD=FC(FC+CD)$
4. Since $CF=DG$ therefore $BG=AF$
5. Draw $FH \parallel PBG$
6. $\angle X=\angle W$, therefore $\angle A=\angle W$ and $AF=FH$
7. But $BG=AF$, therefore $FH=BG$, also $\angle R=\angle S$ and $\angle Q=\angle V$
8. Therefore $\triangle HFE\cong\triangle BEG$ and also $FE=EG$
9. Therefore $FE-CF=EG-DG$ or $CE=ED$.

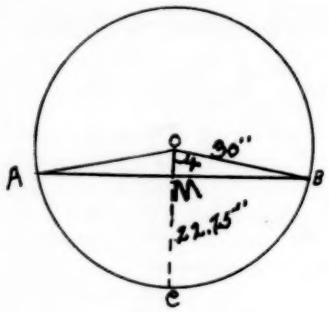
Also solved by D. Moodey Bailey, Athens, W. Va., F. A. Caldwell, St. Paul, Minn., W. E. Batzler, Battle Creek, Mich., A. J. Patterson, Wheeling, W. Va.

NOTE. Chas. W. Trigg in his solution calls attention to the fact that if E is not between A and B, the proportion fails.—EDITOR.

1242.

A cylindrical tank is 12 feet long and 5 feet in diameter. It is placed with its axis horizontal. If a measuring stick shows it to be filled to a depth of $22\frac{3}{4}$ inches, how many gallons does it contain?

Solved by O. B. Kraemer, Battle Creek, Iowa.



Vertical Cross Section

Let AB = level of liquid, and $BOM = X$

$OM = 7.25$ in.,

$OB = 30$ in., $CM = 22.75$ in.

Solution:

$$\text{Cos } X = \frac{7.25}{30} = .24166. \therefore \angle X = 76.015^\circ$$

Area of the circle $= 3.1416 \times 900 = 2827.44$ sq. in.

Area of sector $OCB = \frac{76.105}{360} \times 2827.44 = 597.002$ sq. in.

$MB = \sqrt{900 - 52.565625} = 29.11$ in.

Area of $\Delta MBO = \frac{7.25 \times 29.11}{2} = 105.524$ sq. in.

Area of segment $ACB = 2(597.022 - 105.525) = 982.996$ sq. in.

Volume of liquid $= 982.996 \times 144 = 141,551.424$ cu. in.

Number of gallons $= 141,551.424 \div 231 = 612.777$.

Also solved by D. Moodey Bailey, Athens, W. Va., Gordon Bussard, Spokane, Wash., Jerry Barker, Spokane, Wash., William W. Johnson, Cleveland, Ohio, Mack Tucker, Bremen, Ind., Delbert Eggenberger, Normal, Ill., W. E. Buker and Ellsworth Gosnell, Leetsdale, Pa., LeRoy, Dundee, Mich., A. J. Patterson, Wheeling, W. Va., Charles W. Trigg, Los Angeles, Calif., E. Boyd Everett, Emporia, Kan., and the proposer.

1243. *Proposed by W. E. Baker, Leetsdale, Pa.*

Find consecutive integers whose squares have the same digits. State a general method of finding such pairs if possible.

Solved by D. Moodey Bailey, Concord College, Athens, W. Va.

This is not a solution but merely lists four such pairs of integers, namely: 13 and 14, 157 and 158, 913 and 914, and 4513 and 4514. The first pair is 13 and 14 and it is interesting to note that the sum of the digits making up the other three pairs is also 13 and 14. This fact might possibly enable one to find other such pairs or might also lead to a general solution of the problem.

1244. *Proposed by Raymond Freedman, Philadelphia, Pennsylvania.*

Show that X^n is equal to the sum of the consecutive odd integers (starting with one) multiplied by X^{n-2}.

Solved by Mack Tucker, Bremen, Indiana.

$$S_x=(1+3+5+\cdots+X^{\text{th}}\text{ term})$$
$$=\frac{X}{2}(a+l)\text{ where }a=1,\ l=2X-1$$
$$=\frac{X}{2}(1+[2x-1])$$
$$=X^2$$
$$X^2=(1+3+5+\cdots X^{\text{th}}\text{ term}).$$

Hence multiplying by X^{n-2},

$$X^n=X^{n-2}(1+3+5+\cdots X^{\text{th}}\text{ term}).$$

Also solved by W. E. Bucker, Leetsdale, Pa., A. J. Patterson, Wheeling, W. Va., D. Moodey Bailey, Athens, W. Va., and Charles W. Trigg, Los Angeles, Calif.

1245. *Proposed by Frank B. Allen, Sparta, Ill.*

If $C_0C_1\cdots C_n$ are the coefficients in the expansion of $(1+x)^n$ N a positive integer, show that

$$C_1-\frac{C_2}{2}+\frac{C_3}{3}-\frac{C_4}{4}+\cdots+(-1)^{n-1}\cdot\frac{C_n}{n}=1+\frac{1}{2}+\cdots+\frac{1}{n}.$$

First solution by Boris Garfinnel, Buffalo, N.Y.

By the Binomial Theorem $(1-x)^n=1-C_1x+C_2x^2+\cdots+(-1)C_nx^n$.
Rearranging the terms and dividing by x, we obtain

$$(1)\qquad C_1-C_2x+C_3x^2+\cdots+(-1)^{n-1}C_nx^{n-1}=\frac{1-(1-x)^n}{x}.$$

If we integrate with respect to x, between the limits $x=0$ and $x=1$, the left member of (1) becomes:

$$(2)\qquad \int_0^1(C_1-C_2x+C_3x^2+\cdots+(-1)^{n-1}C_nx^{n-1})dx$$
$$=C_1-\frac{C_2}{2}+\frac{C_3}{3}+\cdots+(-1)^{n-1}\frac{C_n}{n}.$$

The right member of (1) can be transformed by the substitution $x=1-y$

$$\int_0^1\frac{1-(1-x)^n}{x}dx=-\int_1^0\frac{1-y^n}{1-y}dy\int_0^1\frac{1-y^n}{1-y}dy$$
$$(3)\qquad =\int_0^1(1+y+y^2+\cdots+y^{n-1})dy=\left[y+\frac{y^2}{2}+\frac{y^3}{3}+\cdots+\frac{y^n}{n}\right]_0^1$$
$$=1+\frac{1}{2}+\frac{1}{3}+\cdots+\frac{1}{n}.$$

Equating the right members of (2) and (3) we obtain:

$$C_1-\frac{C_2}{2}+\frac{C_3}{3}-\cdots+(-1)^{n-1}\frac{C_n}{n}=1+\frac{1}{2}+\frac{1}{3}+\cdots+\frac{1}{n}.$$

Second Solution by Norman Anning, Ann Arbor, Mich.

Let the given expression on the left-hand side be denoted by $f(n)$.
It follows from the known values of the C's that

$$f(n)-f(n-1)=1-(n-1)/2!+(n-1)(n-2)/3!-(n-1)(n-2)(n-3)/4!+\cdots$$

Multiply both sides by $(-n)$ and add 1.

$$1-nf(n)-f(n-1))=1-C_1+C_2-C_3+=(1-1)^n=0.$$

It follows that $f(n)-f(n-1)=1/n$.

Similarly
$$f(n-1)-f(n-2)=1/(n-1)$$
$$f(n-2)-f(n-3)=1/(n-2)$$
$$\cdots\cdots\cdots\cdots$$
$$f(2)-f(1)=\tfrac{1}{2}.$$

By definition, $f(1)=1$

When we add these n equations, we find that $f(n)$ is equal to the sum of the reciprocals of the first n positive integers. Q.E.D.

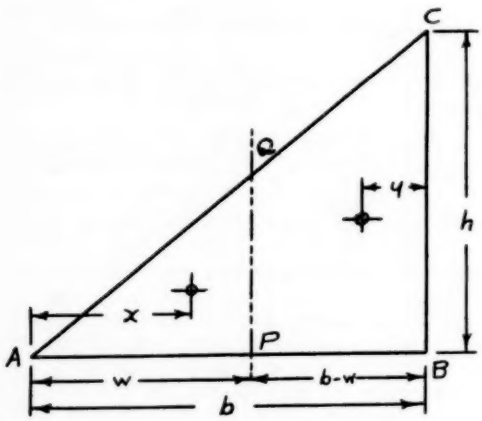
1222. *Proposed by F. H. Wade, Chicago, Ill.*

PROBLEM: Given a triangle with horizontal base b and vertical altitude h, divided into two parts by the vertical line PQ. Required the position of PQ so that the moment of area of left-hand part with respect to A be equal to the moment of area of right-hand part with respect to B. That is, if x and y are the distances to the respective centroids, required to find PQ so that area $APQ\cdot x$ area $BPQC\cdot y$.

This result is of importance in bending of beams.

Solved by Charles W. Trigg, Cummock College, Los Angeles, Calif.

Eliminate X and Y, as given in the figure, from consideration, so that AB may be considered as the X-axis, and either CB or a perpendicular to AB at A as the Y-axis.



If the Y-axis passes through A, the line AC has the equation, $Y=\dfrac{hx}{x}$.

The moment of area of ΔAPQ around this axis is

$$\int_0^w \int_0^{hx/b} x\,dx\,dy.$$

If the Y-axis passes through CB, (and the triangle be swung into the first quadrant which will not affect the moment of area of the trapezoid) the line CA has the equation,

$$Y=\frac{h(b-x)}{b}.$$

The moment of area of $BPQC$ around this axis is

$$\int_0^{b-w}\int_0^{h(b-x)/b} x\,dx\,dy.$$

Equation these two integrals, integrating, and solving the resultatn equation,

$$W=\frac{b}{3}\sqrt{3}=0.5774b$$

That is, $PQ\perp AB$ at a point $0.5774b$ from A.

LATE SOLUTIONS

1238. *John E. Bellards, St. Nazianz, Wis.*

1229. *John E. Bellards, St. Nazianz, Wis.*
Chas. W. Trigg, Los Angeles, Calif.

1239. *Chas. W. Trigg, Los Angeles, Calif.*

1236. *Chas. W. Trigg, Los Angeles, Calif.*

1235. *Chas. W. Trigg, Los Angeles, and E. G. Escott, Oak Park, Ill.*

PROBLEMS FOR SOLUTION

1262. *Proposed by W. E. Batzler, Battle, Creek, Mich.*

Given the position of the circumcenter, an excenter and the incenter. Construct the triangle.

1263. *Proposed by W. E. Buker, Leetsdale, Pa.*

Give a general method of finding integers, a, b, c, d, e, f, so that simultaneously $a+b+c=d+e+f$ and $a^2+b^2+c^2=d^2+e^2+f^2$.

An example is $17+21+28=16+23+27$.

$$17^2+21^2+28^2=16^2+23^2+27^2.$$

1264. *Proposed by Lambert E. Brood, Aliquippa, Pa.*

Three segments, one from each vertex of an equilateral triangle, meet at a point within the triangle in the ratio of 3:4:5. What is the length of the side of the equilateral triangle?

1265. *Proposed by Nathan Nicholson, Philadelphia, Pa.*

Given a circle, O, with chord AB and C its mid point. Thru C draw any two chords DE and FG. Draw lines DG and FE intersecting chord AB at M and N respectively. Prove by methods of elementary geometry that $MC=NC$.

1266. *Proposed by O. T. Snodgrass, Columbia, Mo.*

Given a sphere of radius, a, and a square shaft, with a side of a cross section of the square, x. Find the volume cut out by this shaft whose central axis passes thru the center of the sphere.

1267. *Proposed by Walter Carnahan, Indianapolis, Ind.*

Construct the triangle ABC given the points C and A and the lengths of the lines joining A to the centroid G and to the orthocenter H.

HIGH SCHOOL HONOR ROLL

The Editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

For this issue the Honor Roll appears below.

1242. Hausen Smith, Battle Creek (Iowa) High School, Carl Clader, John Keating, and Paul Schrode, Wilkes-Barre, Pa., Jerry Barker and Elmer Nygren, Lewis and Clark (Spokane) High School.

1241. Hausen Smith, Battle Creek (Iowa) High School, R. G. Wilkinson, Higher Mathematics Club, Hutchinson—Central High School, Buffalo, New York.

This department is pleased at the response of Mathematics Clubs in High Schools. The organization of such clubs shows a fine trend in educational work.

The Simon Gratz High School Mathematics Club of Philadelphia has been cooperating for six years, by submitting and offering problems for solution. It was responsible for the first contribution from a high school club. The club makes serious study of all the problems whose solutions are presented.

The Higher Mathematics Club, Hutchinson Central High School, Buffalo, New York, made a good contribution to this issue.

NOTE.—Problem 1228 in the October, 1932, issue as solved is faulty. The reason given in step 10 not being true in all cases.

The Mathematics Club which solved this problem called attention to the error.

Charles C. Hunt, Cedar Rapids, Iowa, writes as follows: The theorem quoted "is not necessarily true unless in each case adjacent triangles have two vertices in common."

Also, in Problem 1232 there is an error in the value given for h. It should be 33.4 (approximately). The required area is about 1750. The proposer and Chas. W. Trigg both called attention to the error.

A FUEL THAT BURNS IN STEAM

BY B. CLIFFORD HENDRICKS
University of Nebraska, Lincoln

The lecture demonstration experiment about to be described makes an appeal to those witnessing it, both by the intense light emitted by its chemical action, and the novelty of seeing a metal burn in an atmosphere of steam.

Science students are taught that water is doubly effective in extinguishing fires; it reduces temperatures below kindling points and blankets the burning material with steam which crowds air away from it. Most students have never thought of steam as a possible substitute for air in the process of combustion.

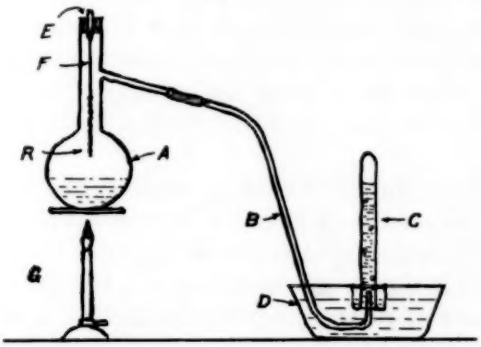
Other teaching possibilities in this experiment are:

Heat conditions the reaction rate of substances.
Water dissociates to an appreciable degree at 1000° C. or above.

Combustible substances, even though gases, may be generated at high temperatures without "taking fire" if the proper supporter is not present.

Different metals may exhibit their relative activities by their combustion in different supporters.

The equipment needed in performing the experiment consists of a 750 cc. liter distilling flask, A, with a 30 or 40 mm. neck, a delivery tube, B, a pneumatic trough, D, and receptacle, C, for the generated gas. A one hole rubber stopper that fits the flask neck is fitted with a piece of copper wire, F, long enough to hold a 10 cm. length of magnesium ribbon, R, folded into a 2 or 3 cm. length, below the curve of the flask, but above the surface of the water.



In performing the experiment the flask is left open until the water has been brought to the boiling point. The ribbon at the end of the wire is then ignited and carefully inserted into the mouth of the flask taking care not to touch its side with the hot burning metal. When the cork is pushed firmly into the mouth of the flask, the generated gas quickly fills the receptacle, C, while the metal continues to burn vigorously in the steam even though the air is entirely excluded.

After the ribbon has been consumed the "ashes," magnesium oxide, may be thoroughly shaken with the hot water in the flask and tested by red litmus which shows a change to the blue. The gas in the test tube, C, may be exploded by exposure to the flame of the burner, G.

Over 83 per cent of the women in the United States are married by the time they are 21 years of age and over 87 per cent by the time they are 33 years old. It is safe to assume, therefore, that a very large majority of girls and women will at some time have the responsibility of organizing and maintaining a home. In view of these facts the need of home economics such as is provided in vocational schools is obvious.

WHAT ABOUT THE MONOCYCLE

By H. Lynn Bloxom
High School, Fort Dodge, Iowa

Ever so often artists decorate the covers of popular science magazines with some sort of one wheeled vehicle in the form of a large hoop which contains a car for passengers. The fact that there is some thought in that direction offers an opportunity to interest the new students of science and direct them into the study of the laws of gyration before they are hardly aware.

It probably does not occur to many that gyroscopic action is responsible for any stability that such a device may possess. If the hoop is lightly built in order to have the unsprung weight as small as possible and there are no major rotating parts, it fails to balance because the main portion of its mass does not revolve.

A rolling hoop stabilizes itself in precisely the same way as a boy riding a bicycle. It turns in the direction it tends to fall and thus brings the opposing forces back into line. To show that this turning effect is due to gyroscopic action and does not appear when the mass of rotating parts is negligible, a simple device may be prepared by stitching the frame of a small gyroscope to

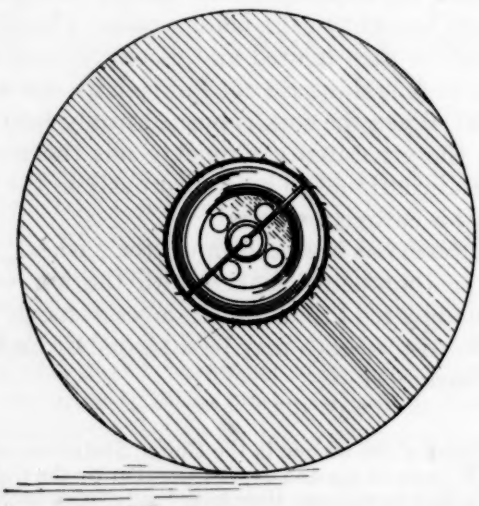


Fig. 1. A gyroscope mounted in a cardboard ring to show why a rolling wheel is stable.

the inner edge of a wide cardboard ring, as illustrated in figure one. If an attempt is made to roll this combination, the heavy wheel does not turn and the small mass that does revolve is unable to properly manipulate the rest and the whole thing flops over awkwardly in a very short distance.

When the heavy wheel is first given a spin so that its rotation agrees in direction with that of the ring, a nice balance obtains as long as there is the slightest forward motion. At the end of its course, however, the combination will be found to spiral down in much the same way as a hoop performs. Any attempt to roll

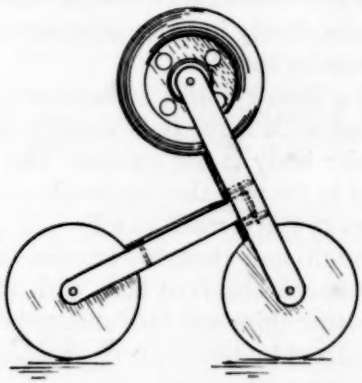


FIG. 2. A gyroscope mounted in the front fork of a model bicycle to demonstrate that a rolling wheel steers itself into a stable attitude in the same manner as the cyclist.

it along a surface in opposition to the direction of spin, meets with sudden interruption. It turns the wrong way and avoids the condition of stability—a thing for the monocyclist to remember.

With the gyroscope rotating, it may be shown that the forward course would be curved in the direction it leans, by tilting it to one side. The response is a quick turn in that direction.

If it is desired to further link this balancing action with the high art of riding a bicycle successfully, a model bicycle may easily be constructed along the lines of the one illustrated in the second figure. A gyroscope rotating in the same direction and in the same plane as the front wheel, controls the front fork. It is done so accurately that such a model may be made to glide forward as if manipulated by a skillful rider. If the fork is locked with wedges so that the gyroscope is unable to guide the bicycle, the effect is the same as a boy experiences when for some reason

or other his bicycle continues on in a straight line contrary to his expectations. The slight stability that a bicycle has of its own account is scarcely noticed when the gyroscope is not spinning. If the direction of spin is opposed to the direction the wheels turn, the model is steered in such a way as to obliterate all traces of stability.

Finally, when the gyroscope is revolving but the bicycle is not in motion, there is no balance regardless of whether or not the fork is locked. This last observation may surprise some advanced students, for many fail to note that a gyroscope resting on two points is as unstable as though it did not rotate and when resting on one, slowly but certainly gravitates earthward, regardless of its angular speed.

Something more than *gyration* is necessary for the type of stability concerned with here. It is equally true that *forward motion* of a circular body is not enough. The two movements must be combined in the way they naturally occur when a hoop, or wheel with a heavy rim is made to roll.

With a little additional thought, anyone should be able to connect the phenomena observed here, with the part the gyroscope plays in piloting ships and airplanes to relieve them of the pitch and roll imparted by the elements in which they move.

SCIENCE QUESTIONS

January, 1933

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland Ohio

Readers are invited to co-operate by proposing questions for discussion or problems for solution.

Examination papers, tests, and interesting scientific happenings are very much desired. Please enclose material in an envelope and mail to Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

AN EXPERIMENTAL QUESTION

612. *Proposed by Herbert S. Lein, Bennett High School, Buffalo, N.Y.*

Suppose you wish to have your coffee piping hot but do not drink it with your meal. When is it best to add cream—immediately after pouring or just before drinking?

(This question has a perfectly sound physical and mathematical answer. EDITOR.)

HEAT FROM ELECTRO-MAGNET

613. The Sunday Plain Dealer (Cleveland Dec. 11, 1932) shows a picture of Miss Dorothy Welch and Mr. Clyde Herrold, students in Mt. Union College, Alliance, Ohio, "frying an egg over a huge electromagnet without any additional heat." Back in 1890, Col. W. H. Morgan of the Morgan Engineering Co. Alliance, began to collect electrical apparatus to perform tricks for guests at "Morgan Castle." After his death the apparatus was given to Mt. Union College.

Are they nature fakirs, or can it be done? Please explain, Alliance; or anyone else.

EDISON GENERAL SCIENCE TEST

614. *General Science test submitted by H. K. Moore, Thomas A. Edison School, Cleveland, Ohio.*

There are 52 questions on the first part of this test which will be published in two instalments. The first instalment of it appears below. The second instalment will appear in February. EDITOR.

THOMAS A. EDISON SCHOOL GENERAL SCIENCE TEST, GRADES 7, 8, and 9. CONSTRUCTED BY H. C. MCGUFEY, L. D. MENNEL AND H. K. MOORE

Name..... Homeroom.....Score.....

Directions: Below are a number of incomplete statements or questions. Five words are given after each statement. One of these words makes the statement true; the others are incorrect. Read each incomplete statement or question carefully, decide which of the words name the truest answer, then write the *Number* (not the word itself) on the line at the right. The samples are correct.

Sample: The sun gives off
(1) air. (2) light. (3) water. (4) coal. (5) iron.....(2)

Sample The earth is
(1) pointed. (2) flat. (3) square. (4) round. (5) cylindrical...(4)

1. Cleveland gets it water supply from the
(1) wells. (2) river. (3) ocean. (4) lake. (5) gulf.....( )
2. Most of our common plants start from
(1) roots. (2) cuttings. (3) seeds. (4) grafts. (5) buds.....( )
3. A compass is used to tell
(1) time. (2) temperature. (3) altitude. (4) distance. (5) direction.....( )
4. Small plants should be watered in the
(1) morning. (2) afternoon. (3) evening. (4) night. (5) noon..( )
5. A healthy blossom develops into
(1) thorns. (2) leaves. (3) fruit. (4) bark. (5) limbs.....( )
6. When one gets all of his teeth he should have
(1) 20. (2) 24. (3) 28. (4) 32. (5) 36.....( )
7. Originally all of our soil came from
(1) water. (2) rocks. (3) the air. (4) moon. (5) Africa.....( )
8. An airplane, in its method of staying up in the air, is most like the
(1) balloon. (2) kite. (3) wind. (4) dirigible. (5) zeppelin....( )

9. What gas do animals throw off through the lungs
(1) methane. (2) helium. (3) hydrogen. (4) carbon dioxide. (5) argon.....( )
10. The moon gets its light from
(1) lightning. (2) the sun. (3) the earth. (4) the stars. (5) itself.....( )
11. Most of our winds come from the
(1) north. (2) south. (3) east. (4) west. (5) overhead.....( )
12. Earthworms live on
(1) roots. (2) organic matter. (3) sand. (4) earth. (5) bugs..( )
13. The lens in a camera is the
(1) handle. (2) view finder. (3) eye. (4) ear. (5) film.....( )
14. Water rises in a lift pump because of
(1) gravity. (2) distillation. (3) atmospheric pressure. (5) height.....( )
15. The point at which a simple lever is supported is called the
(1) base. (2) cam. (3) handle. (4) resistance. (5) fulcrum....( )
16. Heat is transferred from the sun to earth by the process of
(1) radiation. (2) convection. (3) conduction. (4) expansion. (5) resistance.....( )
17. A boat sinks in water until the water displaced equals the weight of the
(1) boat. (2) water. (3) air. (4) people. (5) freight.....( )
18. The name given the revolving electromagnet in the electric motor is
(1) commutator. (2) armature. (3) coil. (4) battery. (5) field magnet.....( )
19. A boat which will not tip over is said to have
(1) gravity. (2) weight. (3) stability. (4) buoyancy. (5) lightness.....( )
20. The name of a solution used in electroplating is
(1) electrolyte. (2) electrotype. (3) grid. (4) commutator. (5) ion.....( )
21. Shutting off the air from the injury is important in treating
(1) burns. (2) fainting. (3) drowning. (4) poisoning. (5) bleeding.....( )
22. Rapid oxidation is referred to as
(1) burning. (2) melting. (3) mixing. (4) joining. (5) fusing..( )
23. A compound of oxygen with another element is a(n)
(1) salt. (2) acid. (3) mixture. (4) base. (5) oxide.....( )
24. Most diseases enter the body through the
(1) ears. (2) feet. (3) hands. (4) mouth. (5) eyes.....( )
25. Which of these is used to kill bacteria
(1) disinfectant. (2) agar. (3) sugar. (4) gluten. (5) casein...( )
26. Tickling the throat with a feather may be used in cases of
(1) burns. (2) fainting. (3) earache. (4) poisoning. (5) bleeding( )
27. Your thinking center is the
(1) cerebrum. (2) medulla. (3) pons. (4) cerebellum. (5) arbor vitae.....( )
28. Steel is a refined form of
(1) lead. (2) iron. (3) zinc. (4) copper. (5) aluminum.....( )
29. The part of the steam engine in which the piston moves is the
(1) steam chest. (2) valve gear. (3) cylinder. (4) slide valve. (5) bell.....( )
30. Which of these is caused by the journey of the earth around the sun?

(1) year. (2) tides. (3) eclipse. (4) friction. (5) day.....( )

31. The locust makes it appearance in great numbers every
(1) 3 years. (2) 5 years. (3) 9 years. (4) 13 years. (5) 17 years..( )

32. The chronometer is a
(1) boat. (2) submarine. (3) compass. (4) clock. (5) sextant..( )

33. What is the heavenly body toward which the north pole always points?
(1) Procyon. (2) Polaris. (3) Pollux. (4) Phobus. (5) Phoebe..( )

34. The cows which ants keep are
(1) spiders. (2) bees. (3) plant lice. (4) flies. (5) goats.....( )

35. What kind of iron comes from the blast furnace?
(1) cow. (2) dog. (3) horse. (4) sheep. (5) pig.....( )

36. If neutral litmus turns red the compound tested is a(n)
(1) acid. (2) oxide. (3) element. (4) alloy. (5) base.....( )

37. The process of obtaining metals from their ores is called
(1) conductivity. (2) oxidizing. (3) smelting. (4) filtering. (5) lining.....( )

38. A molecule of water contains more than one kind of
(1) compound. (2) base. (3) acid. (4) atom. (5) mixture.....( )

39. The electrical unit of resistance is the
(1) ohm. (2) relay. (3) ion. (4) ampere. (5) volt.....( )

40. An instrument for recording temperature is the
(1) radiometer. (2) thermometer. (3) thermograph. (4) altimeter. (5) graph.....( )

41. Transferring heat by means of currents of gases or liquids is called
(1) conduction. (2) vaporization. (3) convection. (4) radiation. (5) piping.....( )

42. The tilt or slant of the earth's axis causes the
(1) night. (2) day. (3) storms. (4) year. (5) seasons.....( )

43. The unit for the measure of work is the
(1) foot-pound. (2) kilogram. (3) liter. (4) watt. (5) ton....( )

44. Milk is made safe by
(1) washing. (2) pasteurizing. (3) filtering. (4) distilling. (5) freezing.....( )

45. The attraction for the earth for objects on it is called
(1) cohesion. (2) adhesion. (3) suspension. (4) gravity. (5) stability.....( )

46. How many years do biennial plants live?
(1) 1. (2) 2. (3) 3. (4) 4. (5) 5.....( )

47. Water enters a plant through the
(1) leaves. (2) trunk. (3) roots. (4) branches. (5) buds....( )

48. A device for changing iron to steel is the
(1) blast furnace. (2) oven. (3) forge. (4) open hearth. (5) ladle( )

49. The name of the acid in vinegar is
(1) acetic. (2) citric. (3) butyric. (4) bromic. (5) sulphuric...( )

50. Heat in a bicycle pump is caused largely by
(1) air. (2) work. (3) perspiration. (4) sweat. (5) friction....( )

51. Smoke is composed of bits of
(1) sand. (2) carbon. (3) dye. (4) oxygen. (5) xenon.....( )

52. The name of the large nerve leading from the eye is
(1) styptic. (2) auditory. (3) optic. (4) olfactory. (5) tactile..( )

JONES IS THE ENGINEER!!

In October, the Editor promised a solution to prove the above. The solution was misplaced. Readers who sent in inquiries asking for the missing solution, please note. EDITOR.

595. Who is the Engineer?

A train is operated by three men, Smith, Robinson, and Jones. They are fireman, engineer, and brakeman, but not respectively. On the train are three business men of the same names. A Mr. Smith, a Mr. Robinson, and a Mr. Jones. Consider all the data about all concerned.

1. Mr. Robinson lives in Detroit.
2. The brakeman lives half way between Chicago and Detroit.
3. Mr. Jones earns exactly $2,000 a year.
4. Smith beat the fireman at billiards.
5. The brakeman's nearest neighbor is one of the passengers and earns exactly three times as much as the brakeman.
6. The passenger whose name is the same as the brakeman's lives in Chicago.

Solution by Roscoe Powers, Indianapolis, Indiana

It is explicitly stated that the list of trainmens names and the list of train operators do not correspond respectively. Call this datum *a*.

The business men are denoted by Mr., the trainmen are not so denoted. Call this datum *b*.

By datum *a:*

(1) The firemen cannot be Smith but can be Robinson or Jones;

(2) The engineer cannot be Robinson but can be Smith or Jones;

(3) The brakeman cannot be Jones but can be Smith or Robinson.

By datum 6 and statement (3) the passenger of the same name as the brakeman is either Mr. Smith or Mr. Robinson. But by datum 1 Mr. Robinson lives in Detroit.

Therefore by datum 6 the passenger is Mr. Smith.

Therefore by datum 6 the brakeman is Smith.

By statement (2) the engineer is either Smith or Jones, but it has just been proved that Smith is the brakeman.

Therefore the engineer is Jones.

(Data 2, 3, 4 and 5 are irrelevant to the solution.)

Another Solution by C. L. Rumrill, Hutchins Advertising Company, Rochester, New York

In the October issue of SCHOOL SCIENCE AND MATHEMATICS you have the problem "Who Is The Engineer"?

I arrived at the conclusion that Smith is the engineer, hinging the solution on the fact that 2,000 is not exactly divisible by 3.

You had a notice that the solution would be in the November issue but I was unable to find it. Will you tell me whether my solution is correct and just what the proper steps are in obtaining the right answer?

In spite of Powers' reasoning, Jones the Editor insists that Smith is the Engineer!!!

CAN A "SUGAR EAT" BE SCIENTIFIC

615. *Proposed by R. B. Simon, Western Reserve Academy, Hudson, Ohio. W. G. Vinal, School of Education, Western Reserve University, F. R. Bemisderfer, East Technical High School, Cleveland, and others.*

Demonstration will be held at Hudson, Ohio, on Saturday, March 18, 1933.

Come and See!!!

Parking for autos on Western Reserve Academy Campus.

All Pennsylvania trains stop at Hudson.

Those arriving by air plane will find a convenient landing field.

TRICK QUESTIONS

Send them in, to Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

MILK PASTEURIZED BY CONDUCTING ELECTRICITY

You may be drinking milk these days which has been pasteurized, not by heat from fire, but by the passage of an electric current. For apparatus which guarantees the safety of milk in this electrical manner has already been installed in seventeen plants in six states and two foreign countries, and has a daily output of approximately 30,000 gallons, Prof. C. G. King of the University of Pittsburgh reported to the Electrochemical Society.

Because of its mineral salts, milk readily conducts electricity. At the same time the liquid offers enough resistance to the passage of current to cause the electricity to give up heat to the milk.

"The possibility of an electrical or electrochemical effect upon bacteria in addition to the heat effect has been considered," Dr. King said, "but at present there is no clear evidence from which the question can be answered. Uniform heating accounts for the major effect, however, and it therefore seems preferable to consider tentatively the entire bacterial effect due to heating."

Tests by state health officials for organisms responsible for tuberculosis, undulant fever, sore throat and typhoid fever, were said to have proved the efficiency of the process. Special tests were also made upon the colon bacillus, thermophiles and many spore bearers.

TAILOR-MADE HIGHWAY SURFACE

A half-mile of gravel road near Baton Rouge was resurfaced with cotton cloth in tests which may yield a quick and economical method of modernizing America's millions of miles of dirt "farm-to-market" roads and make a new market for surplus cotton. Arnold M. Davis was the engineer in charge of construction.

South Carolina, Texas and Georgia are also experimenting with cotton-surfaced roads and Louisiana and Oklahoma plan to install additional "test mileage." It is reported that a strip of "cotton road" laid in South Carolina six years ago and exposed to usual traffic conditions has required no repair attention and is still in excellent condition. Bound down with an asphaltic substance and given a top dressing of oiled gravel to meet the grind of the wheels, cotton increases the life of a road by making it thoroughly waterproof.—*Science Service.*

BOOKS RECEIVED

Linguistic Analysis of Mathematics, by Dr. Arthur F. Bentley, Cloth. Pages xii+315. 14.5 21 cm. 1932. The Principia Press, Bloomington, Indiana.

Health Studies, Home and Community, by F. M. Gregg, Department of Psychology and Education, Nebraska Wesleyan University and Hugh Grant Rowell, Assistant Professor of Health Education, Teachers College, Columbia University. Cloth. Pages vi+258. 12.5 x 19 cm. 1932. World Book Company, Yonkers-on-Hudson, New York. Price 76 cents.

Health Studies, Personal Health, by F. M. Gregg, Department of Psychology and Education, Nebraska Wesleyan University and Hugh Grant Rowell, Assistant Professor of Health Education, Teachers College, Columbia University. Cloth. Pages vi+314. 12.5 x 19 cm. 1932. World Book Company, Yonkers-on-Hudson, New York. Price 84 cents.

Standard Service Algebra, by G. M. Ruch, College of Education, University of California and F. B. Knight, College of Education, University of Iowa. Cloth. Pages xiv+528. 12.5 x 18.5 cm. 1932. Scott, Foresman and Company, 623 South Wabash Avenue, Chicago, Illinois. Price $1.32.

Cultural Natural Science for the Junior High School, by Paul Ammon Maxwell, Professor of Education, Peru State Teachers, Peru, Nebraska. Cloth. Pages xiii+149. 15 x 23 cm. 1932. The Williams and Wilkins Company, Baltimore, Maryland. Price $2.00.

Modern Business Geography, by Ellsworth Huntington, Research Associate in Geography, Yale University and Sumner W. Cushing, Late Head of the Department of Geography in the State Normal School, Salem, Massachusetts. Revised Edition. Cloth. Pages xii+352. 16 x 24 cm. 1932. World Book Company, Yonkers-on-Hudson, New York. Price $1.96.

Objective Exercises in Units of Plane Geometry, by William W. Strader and Lawrence D. Rhoads of the William L. Dickinson High School, Jersey City, N. J. Paper. Pages iv+82. 20 x 27 cm. 1932. John C. Winston Company, 1006–1016 Arch Street, Philadelphia, Pa. Price 48 cents.

Creative Science, by A Modern Job. Cloth. Pages vi+382. 11 x 18 cm. 1932. The Lake Shore Press, 232 E. Erie Street, Chicago, Illinois. Price, blue Morocco, gilt edges with marker $5.00, in cloth, $3.00.

A Short Course in Trigonometry, by James G. Hardy, Professor of Mathematics in Williams College. Cloth. Pages ix+181+xx+143. 13 x 20 cm. The Macmillan Company, 60 Fifth Avenue, New York, N. Y. Price $2.25.

Spiel Und Spielzeug im Physikunterricht, by Dr. G. Dussler. Paper. 79 pages. 20 x 27 cm. 169 figures and 26 tables. 1932. Otto Salle, Frankfurt A.M.

PAMPHLETS RECEIVED

Accredited Secondary Schools in the United States. Supplement to Bulletin, 1930, No. 24. 38 pages. 15 x 23 cm. Superintendent of Documents, U. S. Printing Office, Washington, D. C. Price 5 cents.

Biennial Survey of Education in the United States 1928–1930. Chapter VI. Statistics of Public High Schools 1929–30. Prepared in the Division of Statistics by Emery M. Foster, Chief and Russell M. Kelley, Assistant Statistician with the Cooperation of Carl A. Jessen, Specialist in Secondary Education. Bulletin No. 20, 1931. 95 pages. 15 x 23 cm. Superintendent of Documents, U. S. Printing Office, Washington, D. C. Price 10 cents.

Biennial Survey of Education in the United States 1928–1930. Chapter II. Statistics of State School Systems 1929–30. Prepared in the Division

of Statistics, Emery M. Foster, Chief and by David T. Blose, Assistant Statistician with the Cooperation of Walter S. Deffenbaugh, Chief of American Schools of Division. Bulletin No. 20, 1931. 75 pages. 15 x 23 cm. Superintendent of Documents, U. S. Printing Office, Washington, D. C. Price 10 cents.

An Experimental Study of Superstitions and Other Unfounded Beliefs as Related to Certain Units of General Science, by Otis W. Caldwell and Gerhard E. Lundeen, Institute of School Experimentation, Teachers College, Columbia University. 138 pages. 15 x 23 cm. Published by the Bureau of Publications, Teachers College, Columbia University, New York, N. Y. Price $1.25.

A Guide to Thesis Writing, by Paul Reed Morrow, Director of Educational Research, University of Georgia and Willard Oral Mishoff, Assistant Professor of Library Science, George Peabody College for Teachers. Pages iv+16. 15 x 23 cm. 1932. Bureau of Educational Research, Peabody Hall, University of Georgia, Athens, Georgia.

Engineering: A Career, A Culture prepared by the Education Research Committee of the Engineering Foundation with the active cooperation of groups in six national engineering societies. 61 pages. 15 x 23 cm. 1932. Engineering Societies Building, 29 West 39th Street, New York, N. Y.

BOOK REVIEWS

Essentials of College Chemistry, by B. Smith Hopkins, Professor of Inorganic Chemistry in the University of Illinois, Author of "General Chemistry for Colleges," "Chemistry of the Rarer Elements" etc. First Edition. Pages vi+544. 14.5 x 22 x 3 cm. 195 figures. Cloth. 1932. $3.24. D. C. Heath & Co.

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Dipping into the text here and there we find the treatment clear and concise. It is modern in every way as far as a decent conservatism will permit. One admires the neatness with which the essential conclusions are presented with out all of the mathematical details in such cases as Moseley's Atomic Number Law and the discussion of the Mass Spectrograph. The treatment of the very essential subject of oxidation and reduction from the moden viewpoint is excellent as is the discussion of neutralization.

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FRANK B. WADE

Organic Chemistry, by G. Albert Hill, Professor of Organic Chemistry, Wesleyan University, and Louise Kelly, Professor of Organic Chemistry, Goucher College. First Edition. pp. viii+564. 15.5 x 22 x 3.4 cm. 18 Figures. Cloth. 1932. Price $3.00. P. Blakiston's Son and Co., Inc., 1012 Walnut St., Philadelphia, Pa.

This text is elementary but comprehensive in character, providing a survey course for non-professional students or a foundation course for premedical or biological work. There is a brief biographical historical chapter at the beginning of the book followed by an introductory chapter in which comparisons are made between inorganic and organic substances and the types of formulas in use for organic compounds are introduced. Then follow thirty-six chapters of systematic treatment of the principal classes and types of organic compounds beginning, as is usual, with the saturated hydrocarbons and following with the unsaturated, the halogen derivatives, then the alcohols, ethers, aldehydes and ketones, etc.

After the carbohydrates have been considered we have a number of chapters on the aromatic compounds, followed by special chapters on dyes, alkaloids and plant and animal substances. The work is scholarly and classical in style. We find such modern topics as free radicals and shared electrons mentioned but no extensive applications of the electron theory are attempted.

College teachers who are seeking a text of this type should make a study of this new book.

FRANK B. WADE

Recent Developments in the Teaching of Geometry, by J. Shibli, Ph.D., The Pennsylvania State Teachers College. viii+252 pp. J. Shibli, Publisher. State College, Pennsylvania. Price $2.25.

The book presents an investigation of the problems relating to the teaching of geometry. What these problems are and what solutions have been attempted, especially since the beginning of the present century, constitute the theme which the author treats in a satisfactory manner. It is an account of the significance of the subject in education, and tells the story that geometry has played in the educative process for over two thousand years; of the changes which Euclid's original organization has undergone from its inception to the present time; of the various factors which have in-

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Vol. III: The vegetation of Mt. Desert Island. Maine, and its environment. By Barrington Moore and Norman Taylor. 151 pp., 27 text-figs., vegetation map in colors. June 10, 1927. Price, $1.60.

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J. S. GEORGES

Experiments in Physics, by Leonard Rose Ingersoll, Professor of Physics, University of Wisconsin, and Miles Jay Martin, Associate Professor of Physics, Milwaukee Extension Center, University of Wisconsin. Third Edition. Cloth. Pages ix+301. 13.5 x 20.5 cm. 1932. McGraw-Hill Book Company, 330 West 42nd Street, New York, N.Y. Price $2.50.

Frequently the laboratory work in physics fails to accomplish its purpose and it is a waste of time because students are not taught the real purpose of laboratory study and how to work effectively. An introduction to laboratory work such as the Introduction to this book should be in the hands of the student for frequent reference. It tells how to use the laboratory effectively, how to make and record measurements, how to write a scientific report; it gives a discussion of significant figures and tells how to plot curves.

A sufficient number of experiments is given to allow considerable selection. The experiments range from very elementary to quite difficult. The apparatus needed is practically all standard but includes some of the latest developments. In some experiments provision is made for use of optional types of apparatus. The general plan includes the title of the experiment, object, foreword or brief overview, a description of the apparatus, directions for performing the experiment, a form for recording the data and results, and a number of questions on the experiment. In some cases no form for making the record is suggested in order to give the student an opportunity to practice what he has been taught. Our only criticism on this general plan is that the brevity of the directions may cause students who have little initiative to flounder and waste time.

The appendix is a very valuable part of the manual. It contains good descriptions of the important pieces of apparatus and in many cases gives concise directions for their care and use. Among the instruments described are the analytical balance, optical lever, micrometer microscope, mercury barometer, photometer, and Wheststone bridge. Tables of logarithms and trigonometric functions are included.

G. W. W.

The Metals, Their Alloys, Amalgams and Compounds, by A. Frederick Collins. Illustrated. Cloth. Pages ix+310. 12.5 x 19 cm. 1932. D. Appleton and Company, 35 West 32nd Street, New York, N. Y. Price $2.00.

This is another of A. Frederick Collins' instructive books for girls and boys. While it is somewhat encyclopedic in nature it is written so lucidly that anyone can understand it. Interest is maintained by giving the history of the discovery of each metal along with its properties and uses. For discussion the metals are divided into eight groups such as the common metals, the noble metals, the alkali metals, the radioactive metals, etc. Other chapters discuss the alloys and amalgams. The chapters telling how the metals are mined and extracted from their ores are especially interesting. But it is far more than a book for the entertainment and instruction of young people. It is a valuable handbook and reference book for the layman and for anyone engaged in any type of metal work.

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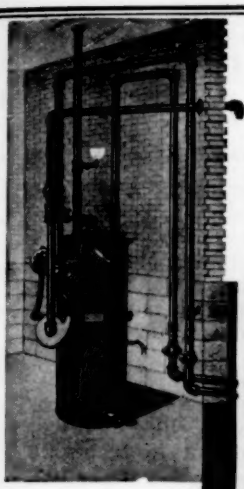

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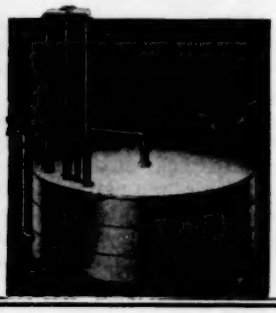

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